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Revision of the genus *Dasyopa* Malloch (Diptera: Chloropidae) from the Oriental Region with description of six new species from India

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ABSTRACT: Six new species of the genus *Dasyopa* Malloch namely, *convexa*, *flavisetosa*, *pentastriata*, *tomentosa*, *unimaculata* and *venadensis* are described from India. *Dasyopa orientalis* Cherian described earlier from India is transferred to genus *Caviceps* Malloch, to which it belongs.The new species described together with the earlier known remaining four species from India represent ten of the nineteen species of the genus so far known from the world.

KEY WORDS: Chloropidae, Oscinellinae, *Dasyopa,* six new species, India.

INTRODUCTION

Andersson (1977) placed the species of *Dasyopa* Malloch under the genus *Trachysiphonella* Enderlein and included them along with *Tricimba* Lioy and related genera under *Aphanotrigonum* genus group proposed by him. Sabrosky (1980) synonymised *Trachysiphonella* with *Dasyopa.* Nartshuk (1983, 1987) in her revisionary works on the family Chloropidae placed *Dasyopa* along with four other genera namely, *Anomoeoceros* Lamb, *Calamoncosis* Enderlein, *Lipara* Meigen and *Pseudeurina* de Meijere under the tribe Liparini which she erected. Of these genera only *Calamoncosis, Dasyopa* and *Pseudeurina* have been reported from India.

Dasyopa is a small genus known by fourteen species from the world of which Cherian (1990) described five from India. On a closer examination of the type and study of more species belonging to the genera *Dasyopa* and *Caviceps* Malloch, *Dasyopa orientalis* Cherian (1990) which was placed with stated reservation under *Dasyopa* in the original description is here by transferred to *Caviceps* Malloch, the genus it comes under. While revising the genus from the Oriental Region, the authors came across six new species from India which are described here.

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These together with the remaining four species reported earlier from India constitute 10 of the 19 species of the genus known from the world.

MATERIAL EXAMINED

The type specimens are retained for the present in the collections of the Department of Zoology, University of Kerala, Trivandrum and shall later be transferred to the National Zoological Collections, Western Ghats Regional Centre, Zoological Survey of India, Kozhikode (Calicut). Types of earlier reported five species from India are in the National Zoological Collections, Zoological Survey of India, Kolkata (Calcutta).

Morphological nomenclature is followed after Mc Alpine (1981).

RESULTS AND DISCUSSION

Genus *Dasyopa* Malloch

1918. *Dasyopa* Malloch, *Bull. Brooklyn ent. Soc*., **13:** 20. Type species: *Dasyopa latifrons* (Loew) (= *Siphonella latifrons* Loew) as *Dasyopa pleuralis* Malloch. By original designation and monotypy.

1936. *Trachysiphonella* Enderlein, *Die Tierwelt Mitteleuropas Insekten,* **6**(3): 187. Type species: *Trachysiphonella pumilio* (Zetterstedt) (= *Oscinis pumilio* Zetterstedt (= *Oscinis scutellata* Von Roser). Monotypy. Synonym, Sabrosky (1980).

Diagnostic Characters: Usually yellow species with very small tomentose frontal triangle, mostly long proboscis and almost always with two to four pairs of *prsc.*

Head with slightly projecting generally longer than wide and tomentose frons with numerous short *fr*; *if* in a row outside triangle along its margin; face concave; facial carina narrow, triangular in upper part and usually reaching epistomal margin; antenna mostly with very fine dense pubescence; *ant 3* wider than long; arista mostly short, basally thickened, rarely long with fairly dense hairs; eye mostly oval, with oblique to horizontal long axis and very dense hairs; gena well developed, sometimes as wide as *ant 3*, normally with numerous hairs in lower half; vibrissal corner almost always projecting; parafacialia linear or indistinct, rarely well developed; palpi cylindrical or flattened, with dark hairs; proboscis normally long, labella sometimes longer than fore tibia; *ovt* and the convergent *pvt* subequal; *ivt* shorter than *ovt*; *orb* 9-13, reclinate; *oc* reclinate, cruciate or convergent; thorax normally yellow with black markings; scutum moderately convex, tomentose, with indistinct depressions along *dc* lines and with longitudinal stripes and dense evenly distributed hairs; scutellum rounded, convex to flattened, tomentose and pubescent like scutum; thoracic bristles usually long and slender but in some species short and fairly stout; *h* 1 very distinct; *npl* 1+2, rarely an additional bristly hair present near inner posterior npl; *pa* 1 and 1 *dc* equal to *npl*; *pa* 2 short; *as* mostly longer than scutellum; *ss* 1-3; legs stout, yellow with darkened areas in some species; tibial

organ narrow; femoral organ "an oval group of warts"; wing with *m-m* cross-vein oblique; haltere yellow or white; abdomen oval, tomentose, usually with brown to dark brown transverse bands; female cerci slender; male cerci free; surstyli relatively large and broad; postgonites distally angular with heavily sclerotised margins and corners; hypandrium open.

***Remarks*: *Dasyopa* Malloch is a relatively small genus which is widely distributed in India. Cherian (1990) described five species from India of which, as stated earlier, *D. orientalis* Cherian is transferred to *Caviceps*. Six new species namely, *convexa, flavisetosa, pentastriata, tomentosa, unimaculata* and *venadensis* from India are described here. A revised key to the species from the Oriental Region is also given. All the 10 species, including the 6 new ones, from the Oriental Region are known only from India and represent 52.6% of the known world fauna of 19 species of this genus.

Distribution: Palearctic, Nearctic and Oriental Regions.

Key to species of *Dasyopa* from the Oriental Region

1. Vibrissal corner prominently projecting beyond anterior margin of eye……….............2

   Vibrissal corner not or only slightly projecting beyond anterior margin of eye…....….6

2. *r-m* cross-vein proximad of middle of discal cell; some distal tarsal segments black…3

   r-m cross-vein distad of middle of discal cell; tarsi wholly yellow or last tarsus of all legs with brown tinge……………………..……..…….........……………………………............…….4

3. *ant* 3 black in females and wholly yellow or medially black with yellow margins in males; arista with dark brown pubescence; terminal sector of M1+2 sinuate and not convex above along its entire length; parafacialia well developed..*prescutellata* Cherian

   ant 3 wholly yellow in males and females; arista with yellow pubescence; terminal sector of M1+2 convex above along its entire length; parafacialia sublinear ....*convexa* Cherian sp. n.

4. Gena as wide as the black *ant* 3; scutum predominantly brownish black…...*humeralis* Cherian

   Gena not more than two-thirds as wide as *ant* 3*; ant* 3 yellow, at most with dark tinge along anterodistal margin; scutum predominantly yellow or brownish yellow…....……5

5 Frons 0.7x as wide as long, projecting beyond eyes anteriorly; vibrissal corner angulate, projecting prominently beyond anterior eye margin; *orb* about 12; scutum densely grey tomentose with 3 brownish black longitudinal bands; terminal sector of M1+2 weakly sinuate, joining costa at apex of wing…..…………….............*venadensis* Jyothi sp.n.

Frons 1.1x as wide as long, not projecting beyond eyes anteriorly; vibrissal corner not angulate, only moderately projecting beyond anterior margin of eye; *orb* about 9; scutum finely grey tomentose with 3 brown longitudinal bands; terminal sector of M1+2 convex above, especially medially and joining costa beyond apex of wing ………………..……………………...……….........................….*unimaculata* Jyothi sp. n.

6. Width of gena one-third that of *ant* 3….. ………………......…*flavisetosa* Cherian sp.n.

Width of gena half or more than half that of *ant* 3…………......……..……………………..7

7. Scutellum nearly subtriangular with flattened disk……………...…………..…………….. 8

Scutellum nearly semicircular with convex disc……………………….......…….……….9

8. Scutum dull black with two sublinear longitudinal striae along *dc* lines; disc of scutellum entirely dull black; terminal sector of M1+2 joining wing margin before apex of wing; hind femur and tibia with diffused blackish brown colouration medially ....……….…………...*meghalayensis* Cherian

Scutum predominantly brownish yellow with broad ill defined median and more defined infuscated lateral longitudinal bands; disc of scutellum yellow with light infuscation confined to median part; terminal sector of M1+2 joining wing margin at apex of wing; hind femur and tibia entirely yellow..…….......................………...*tomentosa* Cherian sp. n.

9. Scutum predominantly brownish black with submedian and lateral sublinear yellow striae; terminal sector of M1+2 very slightly sinuate and hardly convex above in distal half……………..........…………………………………………………….*intermedia* Cherian

Scutum predominantly brownish yellow with median, submedian and lateral infuscated broad, not clearly defined longitudinal striae; terminal sector of M1+2 prominently sinuate and convex above in distal half; ………………..……….*pentastriata* Cherian sp. n.

***Dasyopa convexa* Cherian sp. n. (Plates 1- 4)**

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Male (Pl. 1), *female: Head* (Pls. 2, 3): Length, height and width ratio 24:25:30. Frons slightly narrowing anteriorly, finely and densely grey tomentose, width at vertex half that of head and 0.9x its own length, widening at vertex, very slightly projecting above and in a few specimens a trifle beyond eye margin anteriorly, ending with convex anterior margin and with fairly dense, short, yellow *fr*; frontal triangle very narrow, width less than half that of frons at vertex, grey tomentose, yellow but for black ocellar triangle, reaching hardly beyond anterior ocellus and ending with broadly obtuse apex. Face deeply concave, yellow, densely and finely grey tomentose; facial carina running as a prominent low ridge to epistomal margin; antenna yellow in males and females; *ant* 3 about 1.4x as wide as long; arista short, dark brown, with short

concolourous pubescence. Gena yellow, grey tomentose, divided by a diagonal ridge extending from posterolateral margin to vibrissal corner, width in the middle less than that of *ant* 3, with a few short yellow hairs in lower half; vibrissal corner rounded, projecting beyond anterior margin of eye. Parafacialia sublinear. Eye densely and conspicuously pubescent with nearly oblique long axis. Palpi cylindrical, yellow; proboscis as in *prescutellata,* labella yellowish brown, shorter than fore tibia. Head bristles slender, yellow but in some specimens a few are dark brown; 3-4 posterior *orb* black and more conspicuous, the rest hardly distinguishable from *fr*; other head bristles as in *prescutellata*.

Thorax : A trifle wider than head (10:11). Scutum 1.1x as long as wide, predominantly yellow, densely greyish yellow tomentose with punctate, fairly long yellow hairs and with 3 broad longitudinal blackish brown indistinctly defined bands, running from anterior to almost posterior margin, of which median is again medially divided longitudinally into two and is partly shiny and each submedian one runs along *dc* lines; besides there are two smaller such bands each extending from below transverse suture to nearly base of *pa* 2; all the bands together impart deeply brownish tinge to convex surface of dorsum but for yellow, narrow longitudinal stripes between them; humeral callus dull yellow to yellowish brown. Pleura partly tomentose and partly shiny, yellowish brown to predominantly dark brown, in some specimens with yellow densely tomentose area covering upper and in a few anterior part of *kepst*. Scutellum (Pl. 4): 1.3x as wide as long, half way between semicircular and subtriangular with convex very rarely a little flattened disc, grey tomentose, brownish yellow with dark tinge except for median linear yellow area in some specimens and with punctate, fairly long yellow hairs. Some of the thoracic bristles yellow and a few brown to dark brown; *h* 1 well developed; *npl* 1+2 to 1+3 of which innermost of the posterior three short and the rest subequal and equal to *pa* 1 and 1 *dc*; *pa* 2 about half as long as *pa* 1; a row of 6-8 *prsc* present; *as* not widely separated at base; distance between bases of *as* only a little more than that between bases of *as* and *ss* 1; *ss* 1 half the *as* and *ss* 2 two-thirds the *ss* 1 but more slender.

Wing (Pl. 1): 2.4x as long as wide, hyaline with dark brown costa and brown veins; proportions of costal sectors 2-4 in the ratio 28:19:14; *r-m* cross-vein proximad of middle of discal cell, opposite 0.4 of its length; terminal sector of M1+2 greatly convex above along its entire length, especially in the middle and joining costa beyond apex of wing; R4+5 and M1+2 diverging distally; anal area slightly receding. Haltere yellow, but in some specimens knob with brown tinge medially.

Legs: Predominantly yellow but partly with deep brownish tinge especially on femora and in some specimens even on tibiae; tarsi yellow except for black last two tarsi each of mid and hind legs in both sexes; tibial organ well developed; femoral organ a row of warts.

Abdomen: Narrower than thorax, grey tomentose with dark brown dorsum and sides of basal segments, distal margin of some of the other segments and terminal part of terminal segment with yellowish tinge. Female cerci very slender, yellow but terminally black.

Length: Male 2.0 - 2.1mm; wing : 2.4- 2.6 mm

Female 2.3- 2.5 mm; wing: 2.8 - 3.1mm

Holotype: Male, India. Meghalaya. Nangpo, 18.iv.1980, Coll. P.T.Cherian. *Paratypes*: 20 males, 18 females, collection data same as of holotype.

Etymology: The name of the species is derived from the prominently convex character of its M1+2 vein.

Remarks: *D. convexa* shows affinities to *prescutellata* Cherian but while in the latter *ant* 3 is black in females and wholly yellow or medially black with yellow margins in males, terminal sector of M1+2 is sinuate and not convex above along its entire length and parafacialia is well developed, in *convexa ant* 3 is wholly yellow in males and females, terminal sector of M1+2 is convex above along its entire length and parafacialia is sublinear.

***Dasyopa flavisetosa* Cherian sp. n.** (Plates 5- 6)
urn:lsid:zoobank.org:act:88C15C00-6B0C-496B-B550-ACBA5A1DFE7E

Female (Pl. 5): *Head*: Length, height and width ratio 9:11:13. Frons subparallel, abruptly widening at vertex, brownish yellow, densely grey tomentose, projecting slightly above and a little beyond anterior margin of eye, ending with nearly straight anterior margin and with short punctate yellow *fr*; frontal triangle black, densely grey tomentose, width about half that of frons at vertex, reaching a little beyond anterior ocellus and ending with broadly obtuse apex; a few yellow hairs present in a row along vertex margin. Face brownish yellow, densely grey tomentose, a little concave; facial carina very low, linear, reaching epistomal margin. Basal antennal segments yellow, *ant* 3 about 1.5x as wide as long, yellow in lower half, brownish black in upper half and brownish black along anterodistal and lower margins; arista shorter than in *orientalis*, slender yellow with short fairly dense concolourous hairs. Gena yellow, grey tomentose, width in middle, one-third that of *ant* 3, with a row of whitish yellow hairs on lower margin; vibrissal corner receding, not reaching anterior margin of eye. Parafacialia not developed. Eye large, occupying much of the area of head in profile, suborbicular and unlike in most other species of *Dasyopa* so far known, sparsely and finely pubescent with nearly vertical long axis. Palpi yellow; proboscis short, partly brownish black and partly yellow. Head bristles slender, yellow; *orb* 8, reclinate, three anterior most ones shorter than the rest; other head bristles as in *orientalis*.

Thorax: A trifle narrower than head. Scutum 1.2x as wide as long, dull black with yellowish brown sides, very densely grey tomentose with convex disc which is slightly depressed along *dc* lines and bearing fairly dense short, punctate yellow hairs; humeral callus yellowish brown; part of *anepst* and *anepm* black and grey tomentose; meron, *kepst* and *propleuron (ppl)* shiny, not tomentose, partly dark brown and partly yellowish brown with yellow colouration more prominent on *ppl*. Scutellum 1.5x as wide as long, semicircular with convex black grey tomentose disc bearing punctate hairs as on scutum and with yellow laterodistal

margins with yellow colouration extending to nearly one-third its length distally. Thoracic bristles yellow; *h* 1 only a trifle shorter than *npl*; *npl* 1+2, subequal and equal to *pa* 1 and 1 *dc*; *pa* 2 about half as long as 1 *dc*; *prsc* in a row of about 6, which are hardly longer than scutal hairs; *as* more approximated at base than in *orientalis*, 0.8x as long as scutellum; *ss* 1, 0.6 x and *ss* 2, 0.2x as long as *as*.

Wing (Pl. 6): 2.5x as long as wide, hyaline with yellowish brown veins; proportions of costal sectors 2-4 in the ratio 11:7:5; *r-m* cross-vein almost in middle of discal cell; terminal sectors of R4+5 and M1+2 parallel along almost their entire lengths, the former very weakly bending upwards towards costa terminally, the latter entirely straight and joining costa a little beyond apex of wing; anal area fairly well developed. Haltere yellow.

Legs: Slender, almost wholly yellow but for diffused dark brown incomplete bands in distal halves of femora and short complete bands in basal halves of tibiae; tibial organ present.

Abdomen: Narrower than thorax, brownish black, finely grey tomentose, basal 2-3 segments with yellowish brown tinge on dorsum; female ovipositor very short and slender with pale hairs.

Length: Female 1.9 mm; Wing 2.1 mm

Holotype: Female, India, Kerala, Trivandrum Dist., Kariavattom; 25 m., 7.xii.2005, Coll. A.K. Shinimol.

Etymology: The species derives its name from the yellow colour of its head and thoracic bristles.

Remarks : *D. flavisetosa* shows affinities to *D. Meghalayensis* Cherian but while in the former width of gena is only one-third that of *ant* 3, scutellum is yellow one-third its length distally and M1+2 joins costa beyond apex of wing, in the latter species gena is more than half as wide as *ant* 3, scutellum is wholly black and M1+2 joins costa before apex of wing.

Dasyopa humeralis Cherian

Dasyopa humeralis Cherian (1990) *Oriental insects*, **24**: 358- 359.

Type locality: Tripura: Amarpur: Belonia.

Types studied: *Holotype*: Female, India: Tripura: Amarpur, 16.x.1977, Coll. N. Muraleedharan (ZSI). *Paratype*: 1 female, Tripura: Belonia, 3.x.1977, Coll. N. Muraleedharan. **Other specimens studied**: 3 Females, Kerala: Trivandrum Dist., Kariavattom, 25m, 21.xii.2005. Coll. A.K. Shinimol.

Length: Female 3.0 mm; wing 2.8 mm

Variations: Specimens from Kariavattom, Kerala differ from the types in scutellum being subtriangular and scutum prominently bulging at sides in the area above *pa* 1 and behind transverse suture. It is possible that two species are involved, the specimens from Kerala representing a new species. This can be ascertained only by the study of the male genitalia. Hence they are considered for the present belonging to the same species.

Remarks*: D. humeralis* differs from *prescutellata* Cherian in the nature of frons, number of *orb*, colour of *fr*, thoracic hairs and thorax, position of *r-m* cross-vein, wholly yellow colour of tarsal segments and entirely black antennae. This species was collected from Kerala in southern India 28 years after it was originally collected from Tripura in north-eastern India

Dasyopa intermedia **Cherian**

Dasyopa intermedia Cherian (1990) *Oriental insects*, **24**: 360-361. Type locality:

Tripura: Chandrapur.

Type studied: *Holotype*: Male, India: Tripura: Chandrapur, 7.x.1977, Coll. N. Muraleedharan (ZSI).

Length: Male 1.76 mm; wing 1.55 mm

Remarks: *D.intermedia* is related to *meghalayensis* Cherian but in the former scutellum is nearly semicircular with convex disc and scutum is with submedian and lateral yellow striae but in *meghalayensis* scutellum is subtriangular with flattened disc and scutum is entirely black.

Dasyopa meghalayensis Cherian

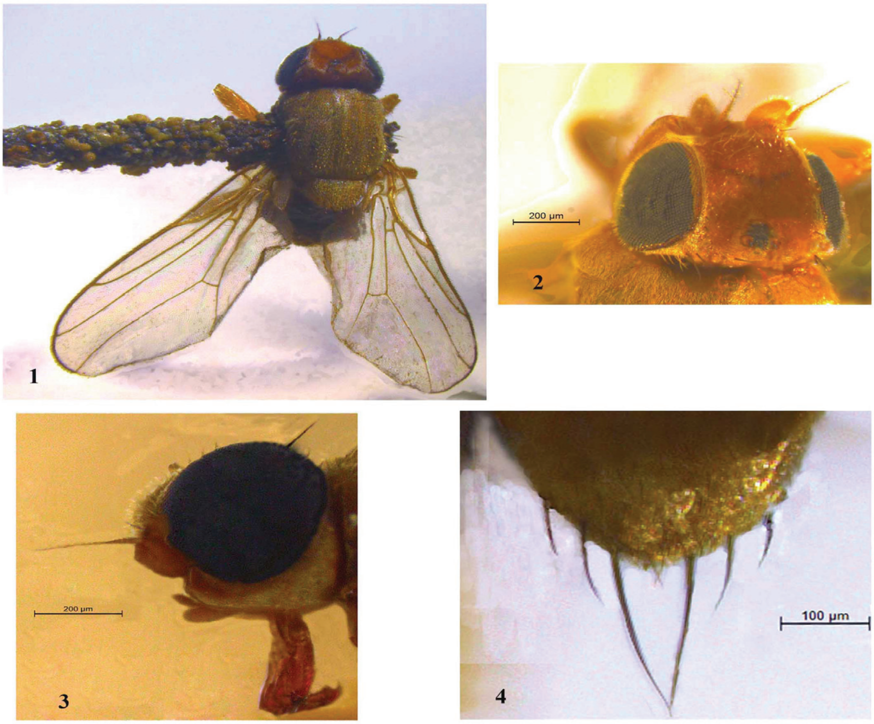
Dasyopa meghalayensis Cherian (1990) *Oriental insects*, **24**: 361-362.

Type locality: Meghalaya: Nangpo

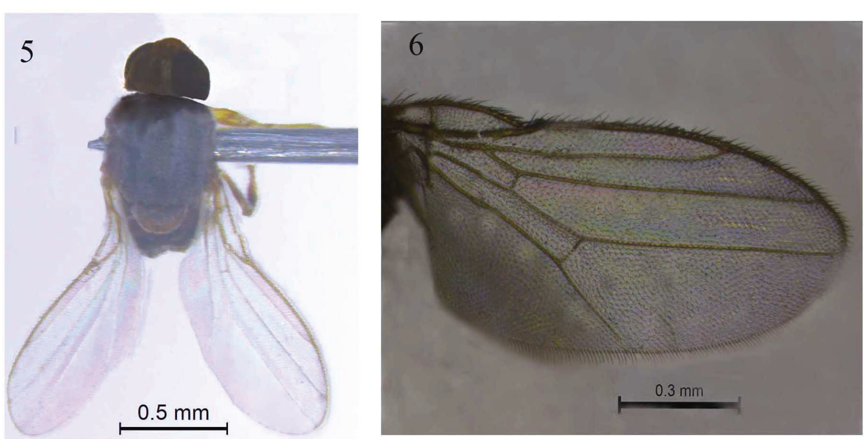
Types studied: *Holotype:* Female, Meghalya: Nongpo, 18.iv.1980, Coll. P.T.Cherian. from Paratypes: 2 females, collection data same as of holotype. the Holotype and the Paratypes, 2 **Other specimens studied**: 1 male and 1 female, collection data same as of the type specimens.

The additional specimens studied belong to the original type series but were not included in the original description. They agree in all respects with the types. This species was hitherto known only by the females and the male is being reported for the first time.

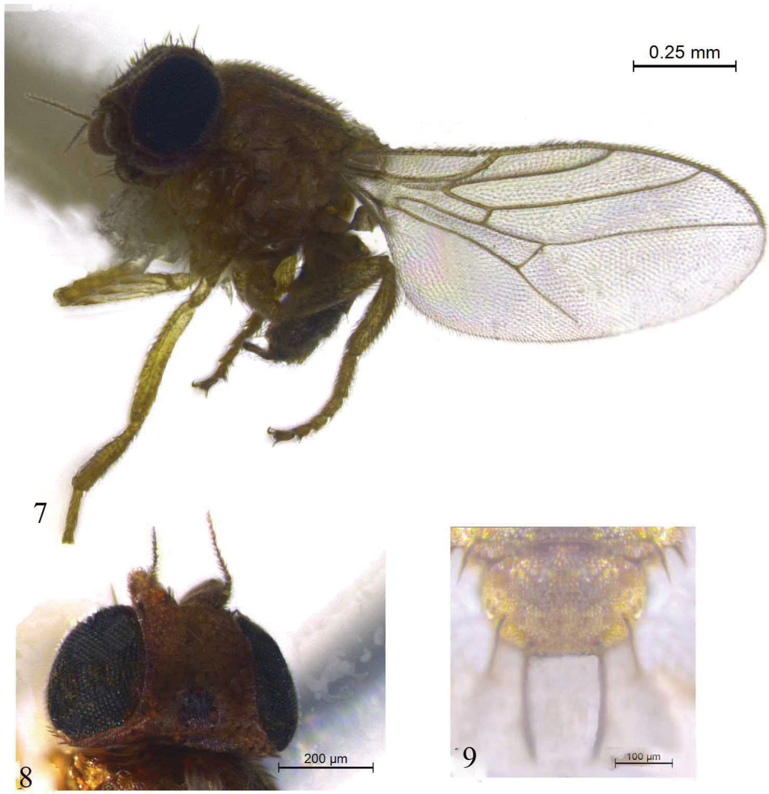
Length: Male 1.8 mm; wing 1.9 mm; Female 1.9 mm; wing 2 mm

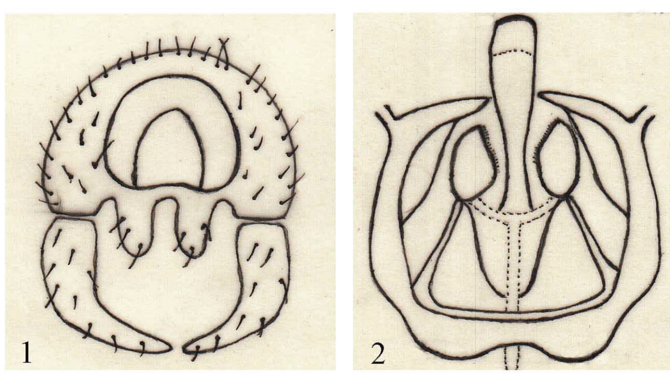


PLATES. 1-4 *Dasyopa convexa* Cherian sp.n. 1- Male fly; 2- head, dorsal view; 3- head, in profile; 4- scutellum.

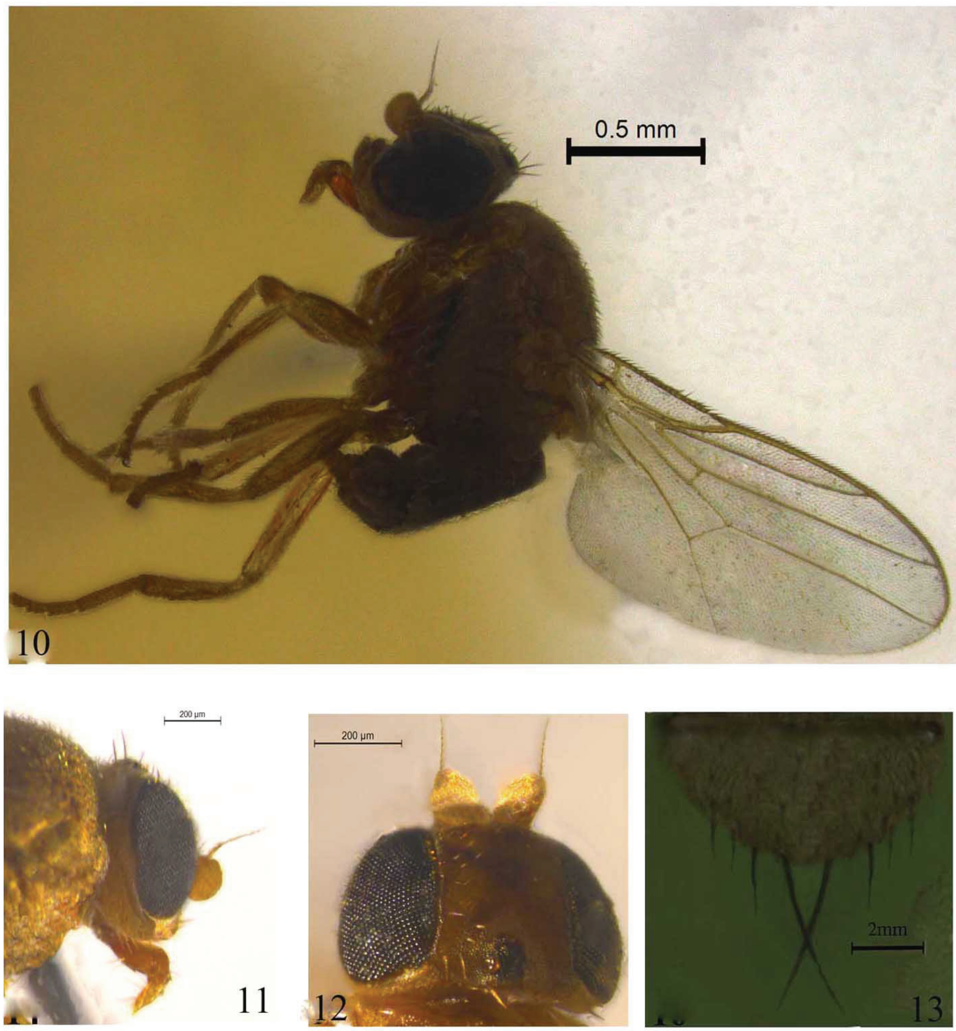


PLATES. 5-6. *Dasyopa flavisetosa* Cherian sp.n. 5-female fly; 6- wing

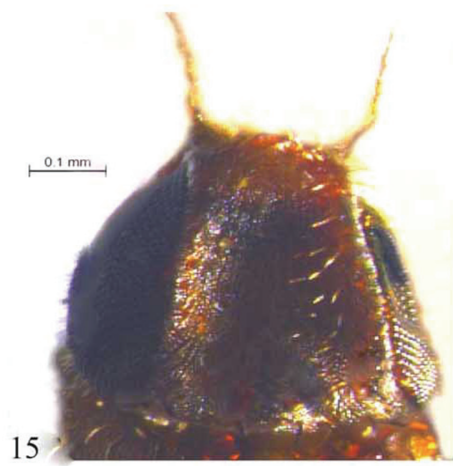




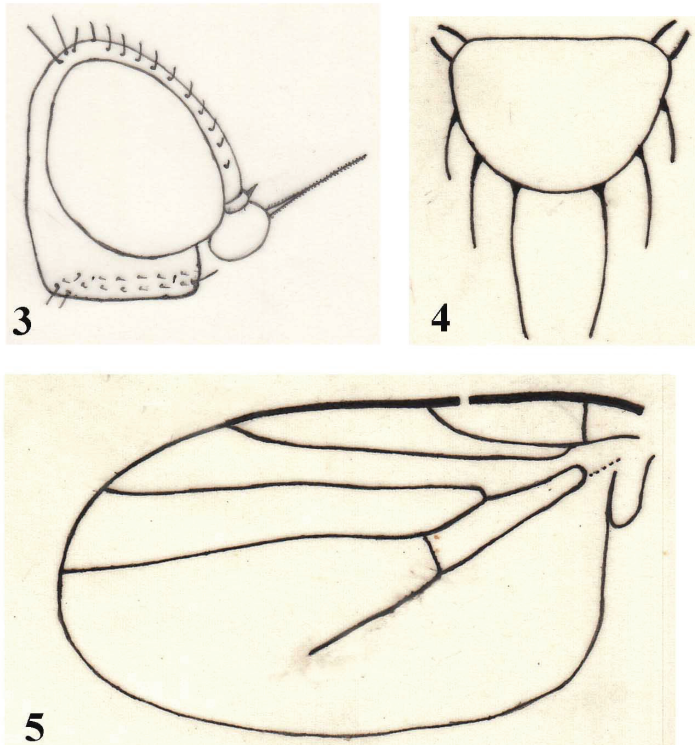
PLATES. 7-9. *Dasyopa pentastriata* Cherian sp.n.
7- Female fly; 8- head, dorsal view; 9- scutellum
FIGURES 1-2. *Dasyopa pentastriata* Cherian sp.n.
1- epandrum; 2- hypandrum & phallic complex



PLATES. 10-13. *Dasyopa unimaculata* Jyothi sp.n.
10- Female fly; 11- head, in profile; 12- head , dorsal view; 13- scutellum.



PLATES. 14-15. *Dasyopa venadensis* Jyothi sp. n. 14- Male fly; 15- head, dorsal view.



FIGURES. 3-5. *Dasyopa tomentosa* Cherian sp.n.
3- head, profile; 4- scutellum; 5- wing.

Remarks: *D. meghalayensis* keys near *intermedia* Cherian but can be differentiated by its subtriangular scutellum with flattened disc and dull and densely grey tomentose thorax. Besides, in the former species there are three pairs of *ss* whereas in *intermedia* there are only 2 pairs of *ss* bristles.

A closer examination of the specimens has revealed that vein M1+2 is weakly concave above in distal half whence it becomes straight before joining costa unlike in the original description where it was stated that M1+2 is straight.

***Dasyopa pentastriata* Cherian sp. n. (Plates 7-9), Figs. 1-2)**
urn:lsid:zoobank.org:act:D6085607-1264-4737-981A-5A600822F7A5

Male, Female (Pl. 7): *Head* (Pl. 8): Length, height and width ratio 5:6:7. Frons nearly parallel sided, width at vertex half that of head and 0.9x its own length, not projecting beyond but

slightly above eye margin anteriorly, ending with straight margin, finely and densely grey tomentose, wholly yellow in some specimens and partly or wholly with deep brownish tinge in others, all specimens with punctate short brownish black *fr;* frontal triangle about half as wide as frons at vertex, deeply brown to dark brown but more densely tomentose than rest of frons, reaching a little beyond anterior ocellus and ending with blunt apex; ocellar tubercle black. Face concave, brownish yellow, densely grey tomentose; facial carina reaching epistomal margin in the form of a low, but slightly distinct ridge. Basal antennal segments yellowish brown to brown; *ant* 3, 1.3x as wide as long, almost suborbicular, brownish yellow but infuscated broadly along anterodistal margin. Arista rather short, slender, brownish black with slender fairly dense concolourous hairs. Gena about half as wide as *ant* 3, brownish yellow, grey tomentose with dark brown hairs as in *intermedia*; postgena concolourous with gena, with a row of short postocular setae; vibrissal corner blunt, reaching but not projecting beyond anterior margin of eye; parafacialia not developed. Eye with fine dense pubescence, long axis oblique. Palpi club-shaped, yellow with dark hairs. Proboscis basally dark brown and distally yellow with slender concolourous hairs. Head bristles relatively short; *orb* about 12, erect to slightly reclinate, longest half as long as *ovt*; rest of cephalic bristles as in *intermedia* but a little shorter and stouter.

Thorax: Scutum as wide as head and 1.2x as wide as long, densely grey tomentose with gently convex brownish yellow dorsum bearing well developed punctae and broad posteriorly abbreviated median and submedian dark brown longitudinal bands of which median in some specimens is divided longitudinally by an yellow stria and each submedian one bifurcates at transverse suture to form short lateral bands. Much of the area of *anepst* and *anepm* dull and grey tomentose; lower margin of *anepst,* practically whole of *kepst* and part of meron not tomentose and shiny; part of meron blackish brown, in some specimens pleural region almost wholly yellow; a row of 6-8 short, black *prsc* also present which are more distinct in some specimens. Scutellum (Pl. 9) tomentose and dark pubescent like scutum, 1.5x as wide as long, semicircular with gently convex disc which is broadly brownish yellow along laterodistal margins and infuscated medially. Thoracic bristles brownish black; *h* 1 a little shorter than *npl*; *npl* 1+2, subequal and equal to *pa* 1 and 1 *dc*; *pa* 2 half as long as *pa* 1*; as,* 1. 2 x as long as scutellum, convergent, more widely separated at base than in *intermedia*; *ss* 1, 0.4x as long as *as*; *ss* 2 not developed .

Wing (Pl. 7): About 2.2x as wide as long, hyaline with brown veins; proportions of costal sectors 2 to 4 in the ratio 4:3:3; *r-m* cross-vein distad of middle of discal cell, opposite 0.55 of its length; terminal sectors of R4+5 and M1+*2* diverging terminally, the latter greatly sinuate, concave above basally, greatly convex above distally and joining costa at apex of wing. Anal area well developed. Haltere yellow.

Legs: In some specimens almost wholly yellow and in a few parts of legs especially mid and hind femora and rarely some tibiae with light dark tinge; tibial organ well developed; femoral organ in the form of a row of 6-7 warts.

Abdomen: Blackish brown, partly subshiny and partly tomentose. Female cerci short, slender, yellow but slightly dark brown terminally and with slender hairs. Male genitalia (Fig.1 & 2) : Epandrium more than 1.5x as broad as long; cerci short and broadly triangular distally, with a few hairs; surstylus in profile broadened at base and gradually narrowing distally; phallapodeme projecting well beyond margin of shallowly concave hypandrium; postgonite in the form of a broad elongated rectangular plate, with a few hairs; basiphallus broadened; distiphallus narrowing distally; basal phallapodemic sclerite broad.

Length : Male 1.2 – 1.4 mm; wing 1.1 – 1.3 mm

Female 1.5 – 1.6 mm; wing 1.32 – 1.5 mm

Holotype: Female: Kerala: Trivandrum: Kariavattom, 25 m, 23. ix. 2005, Coll. A .K. Shinimol. *Paratypes*: 1 Female, collection data same as that of holotype except for the collector P.T.Cherian; 1 Female: Kerala: Trivandrum: Kariavattom, 25 m, 24. vi. 2004, Coll. J. Jasmin; 1 Male: Kerala: Trivandrum: Kariavattom, 25 m, 23. xii. 2005, Coll. A.K. Shinimol; 1 Female: Kerala: Trivandrum: Kariavattom, 25 m, 27. xii. 2005, Coll. A.K.Shinimol; 1 Female: Kerala: Trivandrum: Kariavattom, 25 m, 30. xii. 2005, Coll. Jyothi Tilak; 2 Females: Kerala: Trivandrum: Kariavattom, 25 m, 13. ii. 2006, Coll. Jyothi Tilak; 2 Females: Kerala: Trivandrum: Kariavattom, 25 m, 7. iii. 2006, Coll. A.K. Shinimol; 1 Female: Kerala: Trivandrum: Kariavattom, 25m, 17. iv .2006, Coll. A.K. Shinimol; 1 Female: Kerala: Trivandrum: Kariavattom, 25 m, 17. v. 2006, Coll. A.K Shinimol; 1 Female: Kerala: Trivandrum: Pangappara, 25 m, 10. xi. 2006, Coll. Jyothi Tilak; 1 Female: Kerala: Trivandrum: Kariavattom, 25 m, 15. viii. 2007, Coll. A.K. Shinimol; 1 Male: Kerala: Trivandrum: Kariavattom, 25 m, 11. ix. 2007, Coll. Jyothi Tilak.

Etymology: The species derives its name from the five longitudinal bands on scutum.

Remarks: *D. pentastriata* is closely related to *intermedia* Cherian but it differs from the latter in the colouration of scutum, pleura and scutellum and relative width of gena. Besides, while in *pentastriata* M1+2 is prominently convex above in distal half, *as* are widely separated at base and *ss* 2 is not developed, in *intermedia* M1+2 is only weakly convex above in distal half, *as* are less widely separated at base and *ss* 2 is developed.

Dasyopa prescutellata Cherian

Dasyopa prescutellata Cherian (1990) *Oriental insects*, **24**: 356-358. Type locality:

India: Darjeeling Dist., Goke Forest Rest House.

Types cstudied: *Holotype*: Male, India: Darjeeling: Goke Forest Rest House, 18.iv.1973, Coll. H.S.Sharma (ZSI). *Paratypes*: 33 males, 22 females, collection data same as of holotype.

Length: Male 2.9 mm; wing 2.7 mm; Female 3.2 mm wing 3.0 mm

Remarks: *D. prsecutellata* is related to *scutellata* Von Roser but unlike in the latter, in the former species proboscis is relatively short, parafacialia is well developed, scutellum is convex, thoracic hairs are golden yellow in males and intermittently black and yellow in females and a ridge divides gena in to upper and lower parts. This species has not been reported since it was originally described.

Dasyopa tomentosa **Cherian sp. n. (Figs. 3-5)**

urn:lsid:zoobank.org:act:8A4B5F90-F9FA-4CBD-975D-26572934433A

Male: Head (Fig. 3): Length, height and width ratio 11:13:16. Frons parallel sided, width at vertex half that of head and 0.8x its own length, yellow, finely grey tomentose with short yellow *fr*, slightly projecting above but not beyond anterior margin of eye and ending with straight apex; frontal triangle dull, densely grey tomentose, yellowish brown, projecting hardly beyond anterior ocellus, its width at vertex less than half that of frons; ocellar tubercle black grey. Face deeply concave, yellowish brown, grey tomentose; facial carina reaching epistomal margin as a low but distinct ridge. Basal antennal segments brownish yellow; *ant* 3, 1.4x as wide as long, brownish yellow with dark tinge confined to upper half; arista slender, brownish yellow with short concolourous pubescence. Gena 0.65x as wide as *ant* 3, brownish yellow with punctate hairs in lower half; vibrissal corner almost reaches anterior margin of eye, weakly rounded at apex and almost a right angle but appearing in the specimen to project a little beyond because of the projecting palpus; postgena moderately developed, concolourous with gena. Parafacialia not developed. Eye large, densely and finely pubescent with oblique long axis. Palpi cylindrical, yellow; proboscis rather slender, of moderate length, brownish yellow. Head bristles very short, dark brown; *ovt* and *pvt* subequal and *ivt* a little shorter; *orb* about 10, reclinate longest posterior most one about half as long as *ivt*; *oc* very short, reclinate.

Thorax: Scutum a trifle wider than head (14:13) and 1.1x as wide as long, with moderately convex grey tomentose brownish yellow disc bearing short punctate fairly dense brownish black hairs and with three broad longitudinal bands of which median is slightly and the lateral ones are more deeply infuscated (which under certain angles of illumination appears yellowish). Pleural region grey tomentose but for partly subshiny, brownish yellow *kepst* and meron; *anepst* and upper part of *anepm* brownish black. Scutellum (Fig. 4) 1.4x as wide as long, nearly subtriangular with yellow grey tomentose flattened disc which is slightly infuscated medially and pubescent like scutum. Thoracic bristles relatively short, rather stout; *h* 1 a little shorter than *npl*; *npl* 1+2, subequal and equal to *pa* 1 and 1 *dc*; *pa* 2 very short, slender, less than half as long as 1 *dc*; *as* very widely separated at base, 1.2x as long as scutellum; *ss* 1, 0.4x as long as *as*.

Wing (Fig. 5): Hyaline with yellowish brown veins; proportions of costal sectors 2-4 in the ratio 35: 17: 14; terminal sectors of R4+5 and M1+2 subparellel, very slightly diverging terminally, the latter weakly sinuate along its entire length and joins costa at apex of wing; *r-m* cross-vein distad of middle of discal cell, opposite 0.6 of its length. Haltere yellow, knob partly with deep brown tinge.

Legs: Of medium size; coxae yellow with brown tinge; femora yellow with light brown tinge confined mostly to anterodistal margin; tibiae and tarsi yellow; tibial organ distinct; femoral organ in the form of a row of 6-7 warts.

Abdomen: Much narrower than thorax, dull brownish black with yellowish brown tinge confined to lower posterior margin of second segment and tinge of brown medially on the preceding segments.

Length: Male 2.1 mm; wing : 2.5 mm.

Holotype: Male: India: Tamil Nadu: Palani Hills, 27. iv. 1989, Coll. P.T. Cherian.

Etymology: This species derives its name from its densely tomentose frontal triangle and scutum.

Remarks: *D. tomentosa* keys near *meghalayensis* Cherian but the former has predominantly brownish yellow scutum with three broad infuscated longitudinal bands, yellow scutellum with light infuscation confined to median part of dorsum and yellow femora and tibiae. Besides, in this new species M1+2 joins costa at apex of wing and second sector of costa is 2x the third sector. But in *meghalayensis* scutum is dull black with two sublinear longitudinal striae along *dc* lines, scutellum is entirely dull black, hind femur and tibia are with diffused blackish brown colouration medially, M1+2 joins costa before apex of wing and second sector of costa is only 1.5x the third.

Dasyopa unimaculata Jyothi sp. n. (Plates 10-13)

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Female (Pl. 10): *Head* (Pls.11&12): Length, height and width ratio 13:20:26. Frons nearly parallel sided, slightly widening at vertex, 1.1x as wide as long, projecting a little above but not beyond anterior margin of eye, orange yellow with short dark brown fairly dense *fr*; frontal triangle pale yellow, densely but finely grey tomentose, reaching nearly middle of frons and ending with pointed apex. Face concave, yellow, grey tomentose; facial carina running as a low ridge almost to epistomal margin which is raised up. Basal antennal segments yellow, in dorsal view partly hidden by frons; *ant* 3, 1.4x as wide as long, yellow, finely grey tomentose; arista basally thickened and tomentose, flagellum slender, wholly dark brown with conspicuous concolourous hairs. Gena medially 0.6x as wide as *ant* 3, pale yellow, grey tomentose, narrowing a little anteriorly; vibrissal corner rather rounded, appears angulate and in confluence with epistomal margin and unlike in *venadensis* projecting moderately beyond anterior margin of eye; postgena well developed, concolourous with gena; a row of blackish brown oral setae well developed. Parafacialia in profile developed, concolourous with gena. Eye densely and conspicuously pubescent, with oblique long axis. Palpi yellow; proboscis thickened, well developed, yellowish brown with dark tinge, labella shorter than fore tibia. Head bristles brownish black; *ovt* and cruciate *pvt* subequal; *ivt* shorter than *ovt*; *oc* slightly reclinate,

shorter than *ivt*; *orb* about 10, reclinate, longest a little shorter than *ivt*; *if* in a row of about 6 along outer margin of frontal triangle, hardly longer than *fr.*

Thorax: Scutum as wide as long, finely grey tomentose with small nearly irregular circular non-tomentose spots, ground colour yellow with three broad deeply brownish longitudinal bands of which submedian ones fade off posteriorly around 1 *dc*, disc prominently convex with fairly dense short dark brown hairs; humeral callus yellow. Pleura yellow; *anepst* and *anepm* mostly and *kepst* and meron partly grey tomentose; non-tomentose areas of pleuron shiny; *anepst* along its lower posterior margin with a well developed black macula. Scutellum (Pl. 13) semicircular, 1.3x as wide as long, disc gently convex, concolourous with and tomentose and pubescent like scutum. Thoracic bristles brownish black; *h* 1 as long as *ovt*; *npl* 1+2, subequal and equal to *pa* 1 and I *dc; pa* 2 half as long as *pa* 1; *as* cruciate, not very widely separated at base, 0.9x as long as scutellum; *ss* 1, 0.6x as long as *as;* distance between bases of *ss* 1 and *as s*ubequal to that between the two *as; ss 2* and *ss 3* almost subequal, about two-thirds as long as *ss* 1.

Wing : (Pl. 10): 2.4x as long as wide, hyaline with brownish yellow veins; proportions of costal sectors 2 to 4 in the ratio 20:13:8; *r-m* cross-vein distad of middle of discal cell, opposite 0.63 of its length; terminal sectors of R4+5 and M1+2 slightly diverging distally, the latter gradually becoming slightly convex above much of its length, especially medially and joining costa beyond apex of wing; anal area well developed. Haltere yellow.

Legs: Moderately developed, almost wholly yellow with light infuscation along anterodorsal and anteroventral, posterodorsal and posteroventral margins of some femora and light infuscation on some tibia which is discernable under certain angles of illumination.

Abdomen: Only a little narrower than thorax, suboval, subshiny, partly grey tomentose, yellowish brown with dark tinge on dorsum of distal segments and with short, dark hairs on margins of basal and dorsum of distal segments. Ovipositor moderately stout at base, yellow with slender terminal part which is almost black.

Length: Female 1.9 mm; wing 1.75 mm

Holotype: Female: India: Kerala: Trivandrum: Kariavattom, 25 m, 12.iii.2007, Coll. A.K. Shinimol.

Etymology: This species derives its name from the single black macula on scutum.

Remarks: *D. unimaculata* keys near *venadensis* Jyothi sp. n. but in the former species frons does not project beyond anterior margin of eye and is 1.1x as wide as long, vibrissal corner projects beyond anterior margin of eye, is confluent with epistomal margin and appears angulate, there are only 9 *orb,* scutum is only finely grey tomentose with three brown longitudinal bands and terminal sector of M1+2 is convex above especially medially and joins costa beyond apex of wing. But in *venadensis* frons projects beyond eyes anteriorly and is

only 0.7x as wide as long, vibrissal corner is angulate and does not project beyond anterior eye margin, there are 12 *orb*, scutum is densely silvery grey tomentose and with 3 brownish black longitudinal bands and terminal sector of M1+2 is weakly sinuate and joins costa at apex of wing.

Dasyopa venadensis **Jyothi sp. n. (Plates 14-15)**

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Male (Pl. 14): *Head* (Pl. 15)): Length, height and width ratio 10:11:13. Frons slightly narrowing anteriorly, width at vertex 0.54x that of head and 0.7x its own length, projecting distinctly above and beyond eyes anteriorly forming a roof over bases of antennae and ending with convex apex, deeply yellowish brown except for yellow anterior part, densely grey tomentose and with finely punctate yellow *fr*; frontal triangle densely grey tomentose, dark brown, projecting a little beyond anterior ocellus and ending with obtuse apex; ocellar tubercle projecting above frontal triangle, dull black and grey tomentose. Face deeply concave. Basal antennal segments brownish yellow, partly hidden by projecting frons and hence not visible; *ant* 3 about 1.4x as wide as long, finely grey tomentose, yellow with dark tinge along anterodistal margin; arista short, brownish black with concolourous pubescence. Gena a little less than two-thirds as wide as *ant* 3, projecting beyond anterior margin of eye, brownish yellow; vibrissal corner subangulate, reaching almost anterior margin of eye with conspicuous vibrissae; postgena moderately developed, brownish yellow to partly dark brown and with slender yellow hairs in its lower area. Parafacialia sublinear. Eye densely and conspicuously pubescent, with oblique long axis. Palpi subcylindrical, yellow; proboscis brownish yellow, partly with dark tinge, labella much shorter than fore tibia. Head bristles brownish black; *orb* about12, reclinate, other head bristles as in *humeralis*.

Thorax: Scutum a little wider than head and about 1.2x as wide as long, brownish yellow with convex densely silvery grey tomentose disc bearing finely punctate yellow hairs and with 3 indistinctly defined broad brownish black longitudinal bands of which median is longitudinally subdivided a little behind its anterior margin and extends almost to posterior margin and each submedian one commences a little behind level of humeral callus and is divided behind transverse suture into two of which inner one runs almost to 1 *dc* and outer to *pa* 1. Humeral callus clearly demarcated. Pleura yellowish brown, mostly grey tomentose but for partly shiny and a little infuscated lower part of *anepst*, part of *anepm* and *kepst*. Scutellum 1.4x as wide as long, somewhat rounded in outline with yellowish brown grey tomentose convex disc bearing mostly yellow hairs. Thoracic bristles black; *h* 1 almost as long as *npl,* but more slender*; npl* 1+2, subequal and equal to *pa* 1 and 1 *dc*; *pa* 2 only a little shorter than *pa* 1; *as* a little longer than scutellum, convergent; *ss* 1 nearly two-thirds as long as *as* and *ss* 2 about 0.6x as long as *ss* 1; distance between bases of *as* subequal to that between bases of *as* and *ss* 1.

Wing (Pl. 14): 2.5x as long as wide, hyaline with brown veins; proportions of costal sectors 2 to 4 in the ratio 22:14:9, *r-m* cross-vein distad of middle of discal cell, opposite 0.67 of its length M1+2 weakly sinuate along its entire length, joining costa at apex of wing and

terminally diverging a little from R4+5; anal area moderately developed. Haltere yellow.

Legs: Yellow except for partly deeply brown hind and midfemora; midtibiae with short apical spur. Femoral organ a row of 5-6 warts.

Abdomen: Finely grey tomentose, yellowish brown with dark tinge except at sides of some median segments and with mostly yellow and some black hairs.

Length: Male 1.9 mm; wing 1.7 mm

Holotype: Male, India: Kerala: Trivandrum Dist., Kariavattom, 25 m, 13.ix.2004, Coll. P.T. Cherian.

Etymology: The species derives its name from Venad, the historical name of Travancore, the southern part of present day Kerala State where Travancore is located.

Remarks: *D. venadensis* shows affinities to *humeralis* Cherian but while in the former gena is less than two-thirds as wide as *ant* 3, is yellow and at most only with dark tinge along its anterodistal margin, scutum is predominantly brownish yellow and with longitudinal bands and thoracic hairs are yellow, in *humeralis* gena is as wide as *ant* 3, antennae are wholly black, scutum is brownish black and thoracic hairs are black. Besides they also differ in the relative lengths of costal sectors 2 to 4.

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Abbreviations

anepm - anepimeron; *anepst* - anepisternum; *ant* 2 - second antennal segment; *ant* 3 - third antennal segment; *as* - apical scutellar bristle; 1 *dc* - first dorsocentral bristle; *fr* - frontal hair; *h* -humeral bristle; *if* - interfrontal bristle; *ivt* - inner vertical bristle; *kepst* - katepisternum; *npl* -notopleural bristle; *oc* - ocellar bristle; *orb* – fronto-orbital bristle; *ovt* - outer vertical bristle; *pa* -postalar bristle; *ppl* - propleuron; *prsc*- prescutellar bristle; *pvt*- postvertical bristle; *ss* - subapical scutellar bristle; R 2+3- radius 2+3; R4+5- radius 4+5; M1+2- median vein 1+2.

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Biological control of Eucalyptus gall wasp, *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae) by its native parasitiods

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ABSTRACT: Utilization of native parasitoids *viz. Megastigmus dharwadicus* Narendran and Vastrad (Hymenoptera: Torymidae) and *Aprostocetus gala* Walker (Hymenoptera: Eulophidae) for biological control of eucalyptus gall wasp, *Leptocybe invasa* Fisher and LaSalle (Hymenoptera: Eulophidae) is reported. Two native parasitoids multiplied in the greenhouse were released in a severely affected eucalyptus plantation spread over an area of 1000 ha. A total of 14,000 heavily parasitized galled seedlings, 1400 *M. dharwadicus* and 300 *A. gala* were distributed over a period of six months. The per cent parasitization by these native parasitoids was ascertained before distribution of galled seedlings. Though there was a gradual increase in per cent parasitization, the reduction in gall incidence was not evident up to three months. However, drastic reduction in gall incidence and pest emergence accompanied by very high per cent parasitization was evident within eight months. Post release evaluation conducted during June 2011 and May 2012 indicated the successful control of the pest.

Key Words: Biological control, Native parasitoids, Eucalyptus gall wasp, *Leptocybe invasa, Megastigmus dharwadicus, Aprostocetus gala*

INTRODUCTION

Since its first report from the Middle East during 2000, the Eucalyptus gall wasp, *Leptocybe invasa* Fisher & La Salle has rapidly spread to other areas throughout the world (Aquino *et al.,* 2011; Aytar, 2006; Branco *et al.,* 2006; Dhahri *et al.,* 2010; Gaskill *et al.,* 2009; Karunaratne *et al.,* 2010; Kim *et al.,* 2008; Mendel *et al.,* 2004; Mutitu, 2003; Nyeko, 2005; **Wiley, 2008).** In India it was first reported during 2001 from Karnataka (Anon, 2007) which subsequently

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spread to the neighboring states (ICFRE News letter, 2007; Jacob *et al.,* 2007; Kumar *et al.,* 2007). Recently the pest has expanded its range to northern India (Anon, 2011). The pest causes galls on midribs, petioles and stems of new shoots of eucalyptus. Heavy infestation leads to deformed leaves, shoots and reduction in growth. Invasive gall wasp has become a major constraint in eucalyptus production threatening an estimated eight million hectares of plantation affecting the productivity of paper and rayon industry due to raw material shortage. In Karnataka, the gall wasp was reported to be on an attacking spree and damaged 25 lakh eucalyptus saplings in the nurseries of two major wood based industries (West Coast Paper Mills and Harihara Polyfibres) (Anon, 2007). Three lakh grown up trees were severely affected by *L. invasa* in Punjab (Anon, 2011).

Even after a decade of its existence no effective control measures exist to manage *L. invasa*. Classical biological control has long been considered an environmentally benign approach to controlling invasive pests. In recent years, however, several studies have shown that some biological control agents have deleterious effects on native non-target species (Louda *et al.,* 2003; Samways, 1997). Michaud (2002) opined that classical introductions are increasingly used as a first line of defence against invasive pests regardless of the need. He concluded that the application of the classical approach as an automatic response to every new pest underestimate the potential resilience of native ecosystems to pest invasions. The indiscriminate use of classical approach is environmentally irresponsible as it exposes the ecosystems to an undue risk of non-target effects, including the potential disruption of biological control systems already in place. In the light of increasing evidence of non-target host use and resultant threat to native biodiversity associated with it, the classical biological control needs to be weighed carefully since many exotic species have been released without considering the use of native species (van Lantern *et al.,* 2006). Further, successful fortuitous biological control of introduced pests (Gautam *et al.,* 2009; Michaud, 2002; Nechols, 2002; Rose and Bebach, 1991-92; Shrestha *et al.,* 2010) may render an ill conceived classical approach redundant resulting in waste of time and money. Australian species of *Megastigmus* associated with eucalyptus has been recently reviewed with description of new species (Doganlar and Hassan, 2010). *Megastigmus* sp. and *Aprostocetus gala* Walker were found parasitizing *L. invasa* in India (Vastrad *et al.,* 2010). This native *Megastigmus* sp. parasitizing the invasive eucalyptus gall wasp was later described as *M. dharwadicus* Narendran and Vastrad (Narendran *et al.,* 2010). These native parasitoids were successfully mass multiplied and used to manage gall wasp under green house conditions (Kulkarni *et al.,* 2010). This paper highlights the utilization of native parasitoids to manage the invasive eucalyptus gall wasp in a large monoculture eucalyptus plantation spread over 1000 ha severely affected by the invasive eucalyptus gall wasp since 2007 (Fig 1).

MATERIALS AND METHODS

Mass multiplication

Heavily galled seedlings supplied by The West Coast Paper Mills nursery were used for the mass multiplication. Parasitoids that emerged from eucalyptus samples collected during the

routine survey were released on six month old galled seedlings kept in the green house for mass multiplication following the methodology of Kulkarni *et al.* (2010). A total of 2305 *M. dharwadicus* and 82 *A. gala* were released in the green house between July 2010 and February 2011 (Table 1). Seedlings were kept in the green house for a minimum of 45 days before they were distributed in the plantation. Parasitized galled seedlings and the adult parasitoids collected from the green house were used for field release. Before the field release the extent of parasitization was ascertained from 25 randomly selected seedlings as described by Kim *et al.* (2008).

Table 1: Parasitoids released in the greenhouse for mass multiplication

Months	*Megastigmus dharwadicus*	*Aprostocetus gala*	Total
July 2010	845	00	845
August	201	00	201
September	206	00	206
October	624	00	624
November	153	39	192
December	71	26	97
January 2011	07	17	24
February	198	00	198
Total	**2305**	**82**	**2387**

Field release

The release site belonging to The West Coast Paper Mills, Dandeli consisted of 2-6 year old clones mostly derived from *Eucalyptus tereticornis* spread over an area of 1000 ha in Kulwalli village (located between 15^{o} 32' 07.57" and 15^{o} 34' 06.52" N, 74^{o} 47' 34.04" and 74^{o} 47' 50.51 E) (Fig 1). A total of 14,000 parasitized galled seedlings were distributed at 20 randomly selected spots between September 2010 and March 2011. In addition, 1400 *M. dharwadicus* and 300 *A. gala* collected from the greenhouse were released in the centre of the plantation during October and November 2010 (Table 2). The impact of field release on gall incidence and per cent parasitization was recorded over a period of nine months. Galled samples were randomly collected from four locations on the day on which field release were made. In each location 30

Table 2: Number of parasitized galled seedling distributed and adult parasitoids released at Kulwalli during 2010-11

Month	No. of parasitized alled seedlings	Adult emergence from 25 randomly selected galled seedlings			Parasitization (%) recorded on galled seedlings before distribution			No. of parasitoids released	
		L	M	A	M	A	Total	M	A
22 September 2010	500	75	108	38	48.86	17.19	66.05	-	-
7 October 2010	12,500	17	100	04	82.64	3.30	85.94	860	250
6 November 2010	500	19	34	31	40.47	36.90	77.37	540	50
7 March 2011	500	41	35	65	24.82	46.09	70.91	-	-
Total	**14,000**	**152**	**277**	**138**	**48.85**	**24.33**	**73.19**	**1400**	**300**

L-*Leptocybe invasa,* M-*Megastigmus dharwadicus,* A-*Aprostocetus gala*

Table 3: Gall incidence and per cent parasitization recorded at Kulwalli following the field release of parasitoids

On the day of first release (September 2010)				Second release (October 2010)				Third release (November 2010)				Fourth release (March 2011)			
Number of galls/ 30 cm shoot	Per cent parasitization			Number of galls/ 30 cm shoot	Per cent parasitization			Number of galls/ 30 cm shoot	Per cent parasitization			Number of galls/ 30 cm shoot	Per cent parasitization		
	M	A	Total		M	A	Total		M	A	Total		M	A	Total
Top portion of the sample															
9.80 ± 1.66	0.00	0.00	0.00	13.80 ± 1.32	0.00	0.00	0.00	9.80 ± 1.66	0.00	0.00	0.00	2.30± 1.30	0.00	0.00	0.00
Middle portion of the sample															
7.80 ± 1.40	47.61	0.00	47.61	7.80 ± 1.60	31.81	0.00	31.81	7.80 ± 1.40	47.61	0.00	47.61	3.10± 2.15	90.09	4.95	95.04
4.60± 1.35	35.00	0.00	35.00	5.20 ± 1.16	58.33	0.00	58.33	4.60 ± 1.35	65.00	0.00	65.00	1.40± 1.01	0.00	0.00	0.00
Cumulative															
16.50± 1.66*	42.86	0.00	42.86	15.40 ± 2.85	48.27	0.00	48.27	16.30± 2.51	53.12	0.00	53.12	4.55± 3.35	90.09	4.95	95.04

M-*Megastigmus dharwadicus,* A-*Aprostocetus gala*

centimetre apical shoots from ten eucalyptus plants were randomly collected. The samples were equally divided into top, middle and bottom portion (10 cm each). Different gall stages were recorded on each sample as described by Mendel *et al.* (2004). Based on the number of gall stages recorded, mean gall incidence was worked out for each spot from thirty samples. Later the samples were kept in pin holed polythene bags for pest and parasitoid emergence. Adult emergence of the pest and parasitoids was recorded daily till the cessation of adult emergence. The per cent parasitization was worked out as mentioned in the section 2.1.

RESULTS

Gall incidence and per cent parasitization

On the day of first release

Before the release of parasitoids, mean gall incidence was 16.50 galls/30 cm shoot. Top portion harboured more number of galls (9.80 galls/10 cm) than middle and bottom portions (7.80 and 4.60 galls/30 cm shoot, respectively). Similarly, parasitization by *M. dharwadicus* was 35.00 and 47.61 per cent on bottom and middle portion respectively. During all the observations no parasitization was recorded on top portion of the sample. Total parasitization recorded on the entire sample was 42.86 per cent. Parasitization by *A. gala* was not noticed (Table 3).

Second and third release

No appreciable reduction in the total number of galls was evident during second and third release (15.40 and 16.30 galls/30 cm shoot, respectively). While the number of galls on the middle and bottom portion of the sample remained unchanged, slight increase in gall incidence was noticed on top portion of the sample on the day of second release. Parasitization by *A. gala* was not recorded during the period. Gradual increase in overall per cent parasitization from 42.86 (on the day of first release) to 53.12 was recorded on the day of third release. Similar trend was noticed on the bottom sample. However, about 16.00 per cent decline in parasitization over previous release was noticed on the middle portion of the sample on the day of second release (Table 3).

Fourth release

Impact of field release of parasitoids was clearly evident as indicated by the drastic reduction in the number of galls (4.55 galls/30 cm shoot) and substantial increase in the per cent parasitization. Parasitization due to *M. dharwadicus* and *A. gala* was 90.09 and 4.95 per cent respectively, accounting for 95.04 per cent total parasitization. Effect of such high levels of parasitization resulted total elimination of the gall incidence and as a result no parasitization was recorded three months after fourth release. Since June 2011, no gall wasp incidence and pest and parasitoid emergence has been noticed in the study area.

While overall gall incidence did not change during first three months, gradual decline in pest emergence following field release was clearly evident. Large scale field release on 7 October 2010 resulted in highest recovery of adult *M. dharwadicus* during March 2011. *Aprostocetus gala* not encountered during the previous observations was also recovered in March 2011 (Fig 2). The true impact of field release within six months was indicated by the drastic reduction in the number of galls and adult emergence coupled with significant increase in per cent parasitization. Among the native parasitoids used for the biological control of the gall wasp *M. dharwadicus* was the most dominant.

Post release evaluation

Very few galled plants containing late stage galls were observed during the survey conducted in May 2012. Fresh oviposition damage and early stage galls were conspicuously absent. A single female *M. dharwadicus* emerged from these samples. Emergence of pest was not noticed indicating the effectiveness of native parasitoids one year after the last field release (Plate 1).

DISCUSSION

Classical biological control has been a preferred approach for management of alien insects. However, concerns have been raised about the risks of classical biological control (Howarth, 1991; Samways, 1997; Louda *et al.,* 2003; van Lantern *et al.,* 2006). In the light of concern raised about the risks of classical biological control, present investigations reinforce the utility of native natural enemies to manage invasive pests. The literature is replete with many examples of native parasitoids exploiting the exotic hosts (Aebi *et al.,* 2006; Cooper & Rieske, 2007; La Salle & Pena, 1997). The recently described *M. dharwadicus* has emerged as an efficient parasitoid of *L. invasa* to combat its spread. Contrary to the reported inefficiency of *Megastigmus* spp against *L. invasa* (Protasov *et. al*., 2008) the present findings have conclusively established the effectiveness of native *M. dharwadicus* in combating the menace of the invasive eucalyptus gall wasp. However, classical biological control of the pest has been successfully attempted elsewhere (Kim *et al.,* 2008).

Among the two parasitoids released, *M. dharwadicus* was the most dominant and mainly responsible for reduction in pest incidence. The impact of field release was evident within a couple of months. During the initial period though the decline in gall incidence was negligible, the par cent parasitization increased from 42.86 to 53.12 per cent. The true impact of parasitoid release was clearly evident three months after third release as indicated by substantial reduction in the number of galls (4.55 galls/30 cm shoot) coupled with significant increase in per cent parasitization (95.04%). Faster turn over of parasitoid generation (~ 45 days) compared to the pest (~120 days) has contributed to the overwhelming of the pest by the parasitoids. By the end of June 2011 no fresh oviposition damage and gall incidence was noticed resulting in spectacular control of the pest. While the present study highlights a massive host shift by newly described *M. dharwadicus*, the question of its local host still remains unresolved. However, the other parasitoid used in the study *viz. A. gala* has been reported on *Stenodiplosis*

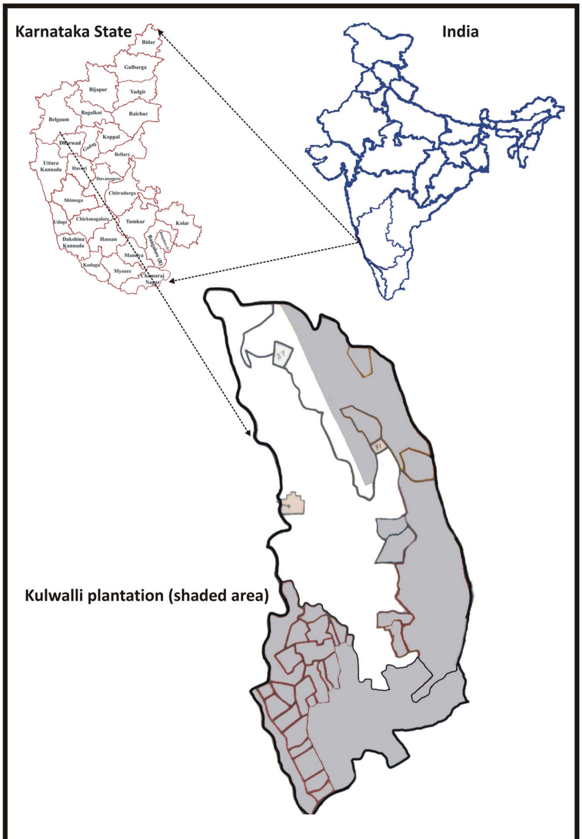

Fig. 1: Site map of study area

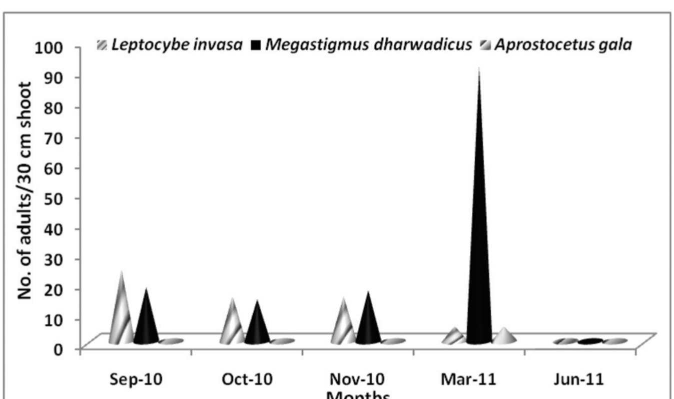

Fig 2: Emergence of the pest and parasitoid adults during 2010-2011

Severely infested eucalyptus plantation at Kulwalli during 2007

Recovery of plantation at Kulwalli during 2012

Plate 1: Impact of native parasitoids on invasive eucalyptus gall wasp

sorghicola and *Diaprepes abbreviatus* (Hall *et al.,* 2001; Nwanze *et al.,* 1998) and we have recovered it from the galls on *Xylia xylocarpa* Roxb. and *Pongamia glabra* Vent.

Though the native parasitoids were recorded as early as 2008, their impact on gall incidence was not discernible. Despite 42.86 per cent parasitization recorded in the beginning of the study and gall incidence still remained high (16.50 galls/30 cm shoot) three months after the first release. The augmentative biological control through repeated field releases of parasitoids resulted in successful control of the pest. Post release evaluation conducted during May 2012 revealed that there has been no resurgence of the pest one year after the last field release. The present study is a rare example of the native parasitoids halting the ravages of an invasion resulting in substantial financial savings on control measures and avoided large scale negative environmental impact due to use of insecticides. It also highlights the importance of considering the use of native parasitoids before embarking on classical biological control.

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First record of *Metrocoris quynhi* Tran and Zettel, 2005 (Insecta: Heteroptera: Gerridae) from India

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ABSTRACT: *Metrocoris quynhi* Tran and Zettel of the genus *Metrocoris* Mayr was described from Vietnam in the year 2005. During the recent surveys to explore the diversity of water striders (Gerridae) in the State of West Bengal and in Himachal Pradesh, *Metrocoris quynhi* Tran and Zettel, 2005, was collected from different localities of Bengal and Himachal Pradesh. This species is widespread in Himalayan region of Bengal but not previously known from India. Hence, it is a new record to India after Vietnam.

Key words: Gerridae, New record, West Bengal, Himachal Pradesh, India

INTRODUCTION

Metrocoris Mayr, 1865 is the most diverse genus among the water striders of the family Gerridae in India. The species diversity of *Metrocoris* Mayr is highest in southern China and Southeast Asia (Tran and Zettel, 2005). These are very small insects with characteristics black markings on yellowish to orange body and are inhabitants of small forested pools, hill streams, slow flowing rivers, waterfalls, shady seepage rocks, and riffles with cobbles.

A total of 65 species are presently reported globally, of which 15 species are known from India (Thirumalai, 2002; Jehamalar and Chandra, 2013). Here, we report *Metrocoris quynhi* Tran and Zettel, 2005 from West Bengal and Himachal Pradesh which was originally described from Vietnam. This species is a new record to India.

MATERIALS AND METHODS

The specimens were collected using a short rectangle-shaped aquatic net from different

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freshwater bodies like rivers, slow-flowing streams and forest pools etc. of Darjeeling Himalaya of West Bengal and Kangra district of Himachal Pradesh. The collected specimens were preserved in 70% ethyl alcohol. The morphological studies were done using a Leica M205A stereozoom binocular microscope. All the measurements were in millimeters (mm). The male genital segment was dissected and immersed in 10% KOH for 30 minutes to dissolve muscles. The photographs were taken with the same Leica microscope. Terminology mainly followed of Chen & Nieser (1993).The specimens (35 males and 36 females) are deposited to National Zoological collection of Zoological Survey of India, Kolkata.

Metrocoris quynhi **Tran and Zettel, 2005**

Material examined: 1M, 3F, 5 nymphs, India: Himachal Pradesh, Kangra district, Panthend village near Saibaba Mandir, Baijnath, 32 02 27 N, 076 38 743 E, 3117 ft, 13.09. 2014, Coll: Dr. K. Valarmathi; 9M, 9F, 6 nymphs, India: Himachal Pradesh, Kangra district, Shahpur, Teh, Rajol Road, Rajol River, 32 10 350 N,076 14 915 E,14.09. 2014, Coll: Dr. K. Valarmathi; 12M, 8F, 11 nymphs, India: West Bengal, Darjeeling District, Rishi River, Rishikhola, 27.17357 N, 88.631104 E, 23.03.2013, Coll: Srimoyee Basu; 1F, 7 nymphs, India: West Bengal, Darjeeling District, Stagnant pool beside Rishi River, Rishikhola, 27.169677 N, 88.635109 E, 23.03.2013, Coll: Srimoyee Basu; 5M, 4F, 1nymph, India: West Bengal, Darjeeling District, Teesta River, Chitre Bridge, 22.03.2013, Coll: S. Basu; 3M, 4F, 3nymphs, India: West Bengal, Darjeeling District, Manjukhola, Phuguri tea estate, 26.85575 N, 88.2091 E, 21.03.2013, Coll: S. Basu; 2M, 4F, 11 nymphs, India: West Bengal, Darjeeling District, Falls near Bunkulung, 26.86776 N, 88.22882 E, 20.03.2013, Coll: S. Basu; 3M, 5F, India: West Bengal, Darjeeling District, Srikhola, 27.132452 N, 88.076729 E, 4.05.2013, Coll: S. Basu.

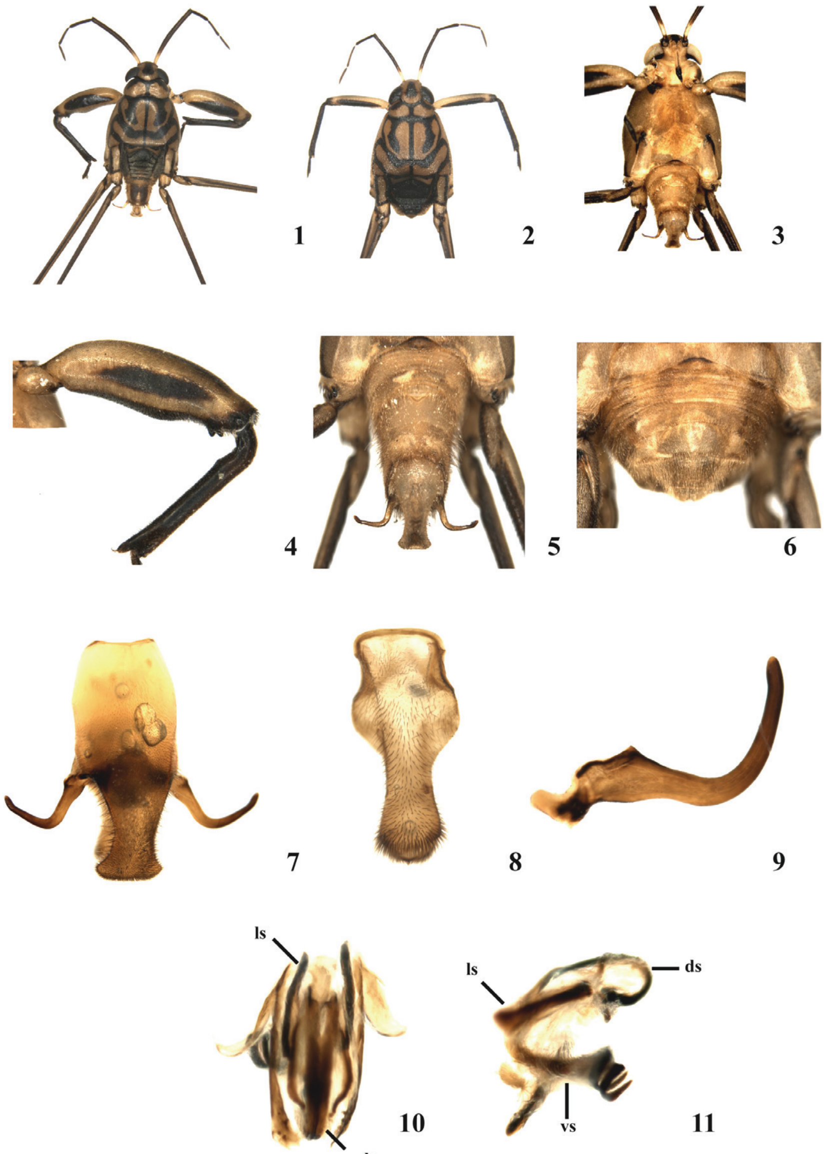
RESULTS AND DISCUSSION

Diagnostic Characters:

Size: Apterous males (35M): Body length 6.1- 6.9, maximum body width 2.64-3.20. Apterous females (35F): Body length 5.3-5.72, maximum body width 3.27-3.40. Macropterous female (1F): Body length 5.4, maximum body width 3.11.

Description of apterous forms

Colour: Dorsally body yellowish orange with distinct black markings. Interocular area with broad arrow shaped marking medially. Antenomere 1 yellow basally, 2^{nd}, 3^{rd} and 4^{th} antennomeres black. Pronotum with ‘T’ shaped black marking, anterolateral margins with two broad black markings. Sublateral stripes broader than lateral stripes in mesonotum. Fore femora with black apical ring and four longitudinal marks, fore tibia and tarsus black. Mid and hind femora slightly yellowish, but tibiae and tarsae dark brown. Ventrally body is bright yellowish orange in colour. Females show similar colour pattern as males.



***Metrocoris quynhi* Tran and Zettel, 2005 (apterous)**

1. Dorsal view of male; 2. Dorsal view of female; 3. Ventral view of male; 4. Ventral view of fore femur and fore tibia; 5. Male abdominal sternites including genitalia; 6. Abdominal sternum VII in female; 7. Male genital capsule showing pygophore and paramere, ventral view; 8. Proctiger in dorsal view; 9. Left Paramere; 10. Male endosomal structure, dorsal view; 11. Male endosomal structure, lateral view (ds- dorsal sclerite, ls-lateral sclerite, vs-ventral sclerite)

Structure: Head length of male (apterous) 0.94 and width 1.54, wider than long, with arrow shaped black marking medially; interocular width 0.72; eye length 0.60 and width 0.35. Length of antennal segments 1st – 4th: 2.46: 0.61: 0.68: 0.67, first antennal segment longer than the combine length of rests. Pronotum wider than long, length 0.553 and width 1.59, slightly bulbous in apterous male. Mesonotum and metanotum 2.47 in width and 1.94 in length. Fore femur strongly incrassate, ratio length/ width: 3.22(2.68/0.83), constricted in apical third, with bipartite apical tooth, without any ventral indentation, with distinct dense short, erected hairs throughout. Inner margin of fore tibia with sub-basal tooth like elevation, with rows of short hairs in both outer and inner margin; fore tibia 2.27 in length; fore tarsomere 1st and 2nd 0.21 and 0.72 in length. Fore femora of female slender, with long stout hairs at basal half. Length of abdomen 2.87 and width 1.62, abdominal segments black, elongated, with dense golden pubescences dorsally and ventrally, longer than wide. In macropterous forms, wing surpassing apex of abdomen.

Genitalia: Male (apterous) abdominal sternite VIII (containing genitalia) elongated, large, rectangular in dorsal view, length 1.45 and width 1.04. Dorsally pygophore prolonged and sub apically constricted, with straight apical margin. Proctiger long distally narrowed, convex on each side anteriorly, with prominent setae distributed throughout, but density increases posteriorly. Paramere long, hook shaped, slightly pointed apically (however, more curved and slender than in the original description and structure may slightly vary among individuals). Endosoma as in fig.10 and 11, dorsal sclerite long and recurved proximally. Female genital segment VII with large medial lobe, with longitudinal ridge laterally from anterior end of hind margin and with small wing shaped lobes, medial lobe sub-trapezoidal, with distinctly notched posterior margin.

Remarks:

Tran and Zettel (2006) have stated that this species belongs to *Metrocoris anderseni* group and is close relative of *Metrocoris genitalis* Chen and Nieser, 1993 from Thailand. The male of *M. quynhi* differs from other species in having hook-shaped paramere and the endosomal sclerite.

Distribution

Vietnam, India.

The distribution *M. quynhi* Tran and Zettel common in the Northern India (Darjeeling Himalayan region of West Bengal and Himachal Pradesh). So far there is no evidence of this species from Southern India. This new record to India was collected mostly from high altitude streams of West Bengal and Himachal Pradesh. It is expected that other Himalayan States of India may also harbor this species.

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Parasitisation of leaf-cutter bees (Megachilidae: Apoidea) by *Melittobia*

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ABSTRACT: Megachilid bees play an important role in pollination of many domesticated and wild plant species. During our attempts to trap nest these bees in southern India, we observed a heavy parasitisation by a species of Melittobia (belonging to *Melittobia hawaiiensis* species group) (Hymenoptera: Eulophidae). Out of 173 megachilid cells collected from 29 nests belonging to four species, 148 cells were parasitized by *Melittobia* sp., with an average of 85.55 % parasitisation and not a single bee emerged from 55.17% of the nests. This is the first record of *Melittobia hawaiiensis* species group parasitizing *Megachile* spp. in India.

KEYWORDS: *Melittobia hawaiiensis* species group, Pollination, Parasitization, Megachile, trap-nests, Bee-hotels

INTRODUCTION

In recent years, there has been an increasing concern on declining pollinator populations, in both natural and agricultural ecosystems (Biesmeijer *et al*., 2006; Potts *et al*., 2010). This decline could be a result of indiscriminate pesticide use (Kremen *et al*. 2002), habitat fragmentation (Mustajarvi *et al*. 2001; Aguilar *et al*. 2006) and/or intensified cultivation practices (Tscharntke *et al*. 2005; Ricketts *et al*. 2008). It is an established fact that pollinating agents are essential for the survival and reproduction of several wild and cultivated plant species (Kearns *et al*., 1998; Klein *et al*., 2007). Among the 18,000+ species of bees in the world, Megachilidae, forms a major group of solitary bees (Michener, 2007), which are involved in pollination of a variety of wild and cultivated plants. The role of leaf-cutter bees as major pollinators of alfalfa, blueberries and pigeon pea has been well established (McGregor, 1976; Free, 1993; Prashanth and Belavadi, 2015).

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To enhance pollination service by leaf-cutter bees, there have been several studies on using artificial nests for increasing their populations (Krombein, 1967; Bohart, 1972; Gaston *et al.,* 2005; Bird, 2010; Pitts-Singer and Cane, 2011). Trap nests, in addition to being excellent nesting sites, may also become attractive to parasites, since a large number of brood cells will be available close to one another (MacIver and Packer, 2015). In the present study we examine the parasitisation of trap nesting Megachile spp. in south India.

MATERIAL AND METHODS

For intensive collection of megachilids, we had placed a total of 117 hollow reeds of *Ipomoea carnea* Jacq. (Fig. 1) for trap nesting leaf-cutter bees on GKVK campus of the University of Agricultural Sciences, Bangalore, India. Fifty reeds were placed on 20.05.2013 and 67 reeds on 1.8.2014. The reeds that were occupied were brought to the laboratory and each reed nest was given a unique number and placed in a separate transparent enclosure. Observations were recorded on the number of cells per nest, number of leaf-cutter bees and parasites emerging from each nest. Voucher specimens of the parasitoid and the leafcutter bees have been deposited in the collections of the Department of Entomology, University of Agricultural Sciences, Bangalore, India. Additional specimens of the parasitoid have been deposited with the National bureau of Agricultural Insect Resources, Bangalore, India.

RESULTS AND DISCUSSION

A total of 29 reeds (24.78%) were occupied by four species of megachilids, viz., *Megachile lerma* Cameron, *M. lanata* (Fab.), *M. disjuncta* (Fab.) and one unidentified species of *Megachile*. The number of cells per nest was 5.96 ± 1.52 (3 to 9; n = 29). One or all the cells in all the nests of these bees were parasitized by a species of *Melittobia* (Fig.2, 3) (Eulophidae: Hymenoptera). A total of 6,022 adults of *Melittobia* emerged from 148 cells with a mean of 43.98 ± 16.20 per cell (range: 20.86 to 94.33; n = 148 cells) (Table 1).

Table 1. Extent of parastisation by *Melittobia* on *Megachile* spp.

Megachile species	# of Nests	# of cells	# of cells parasitized	# of cells *Melittobia*	# of cells *Melittobia* / cell	# of LCB adults emerged
M. lerma	3	18	13	647	49.77	5
M. lanata	6	40	30	1581	52.70	10
M. disjuncta	1	9	3	163	54.33	6
Megachile sp1.	3	13	9	515	57.22	4
Megachile spp.*	16	93	93	3116	33.51	0
Total	**29**	**173**	**148**	**6022**	**40.69**	**25**

*Since all cells in the 16 megachilid nests were parasitized, the host species could not be ascertained

The parasitoid was identified as a member of *Melittobia hawaiiensis* species group based on the following characters: facial grooves convergent above middle of eyes; scape and pedicel clearly paler than flagellum; head relatively narrow, head length greater than genal width; eyes densely clothed with long setae, setae scattered; clypeal margin bilobed and without undulation; nipple on club/claval segment 3, long with one subterminal seta, subterminal seta basal in location; terminal seta on postmarginal vein noticeably longer than those on marginal vein; submarginal vein with 5 long setae; sculpture pattern on mesoscutum and scutellum mid lobes open, particularly on scutellum.

According to Dahms (1984), *Melittobia hawaiiensis* is a complex, and this species group needs detailed morphometric analysis.

Of the four species of leaf cutter bees, *M. lanata* recorded the greatest parasitisation (54.55%) with 1581 parasitoid adults emerging from 30 cells with an average of 52.7 per cell. 72.22 per cent of the 18 cells constructed by *M. lerma* were parasitized by *Melittobia,* with 647 adults emerging from 13 cells with an average of 49.76 per cell. From among the cells of the unidentified species of *Megachile*, a total of 515 parasitoid adults emerged from 63.88 per cent of the cells with a mean of 57.22 per cell. Lowest parasitisation was recorded in *M. disjuncta* (33.33%) with only 163 parasitoid adults emerging from three cells (54.33/cell). From the remaining 16 nests (93 cells) only *Melittobia* adults emerged indicating 100 per cent parasitisation (Table 1; Fig. 4). A total of 3116 parasitoid adults emerged from these nests with an average of 33.50 per cell. On an average, 40 *Melittobia* adults emerged per cell, irrespective of the species of *Megachile* (Fig. 5). This is the first record of *Melittobia hawaiiensis* species group parasitizing *Megachile* spp. in India.

Fig.1 Reeds of *Ipomea cornea* used for trap nesting *Megachile* spp.

Fig. 2 Adult female *Melittobia* sp.

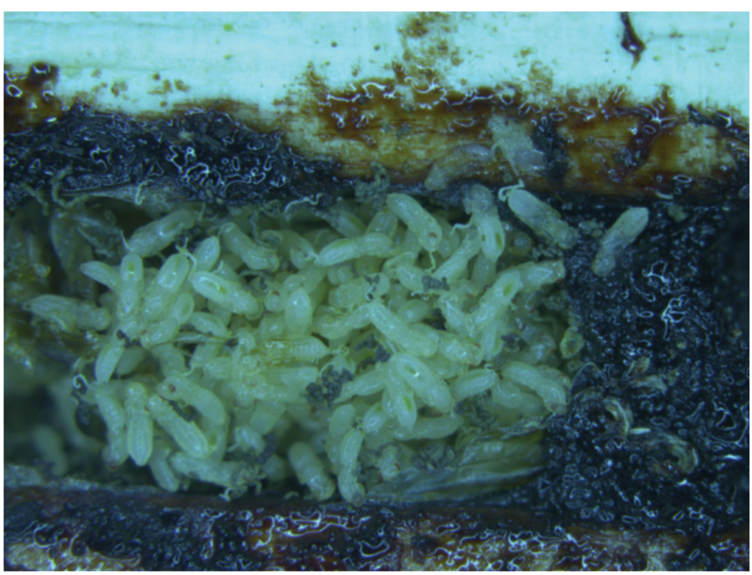

Fig. 3 Prepupae of *Melittobia* sp. in a leaf cutter bee cell

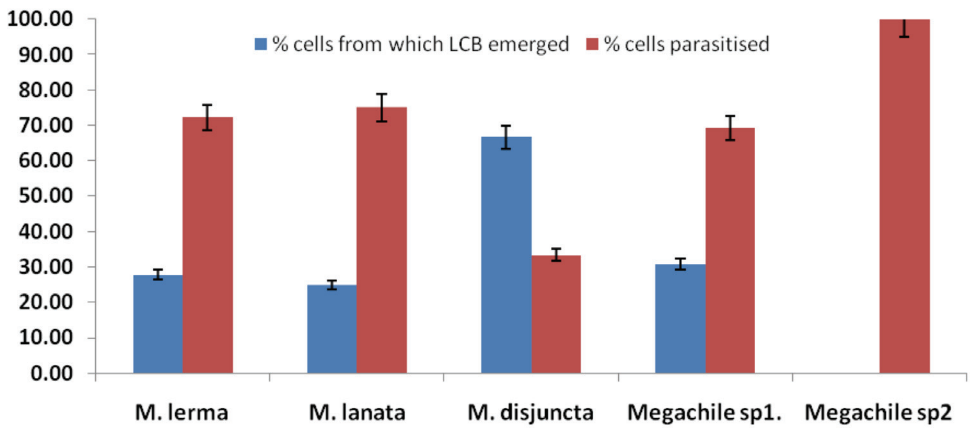

Fig. 4 Percent parasitisation by *Melittobia* and percent survival of *Megachile* spp.

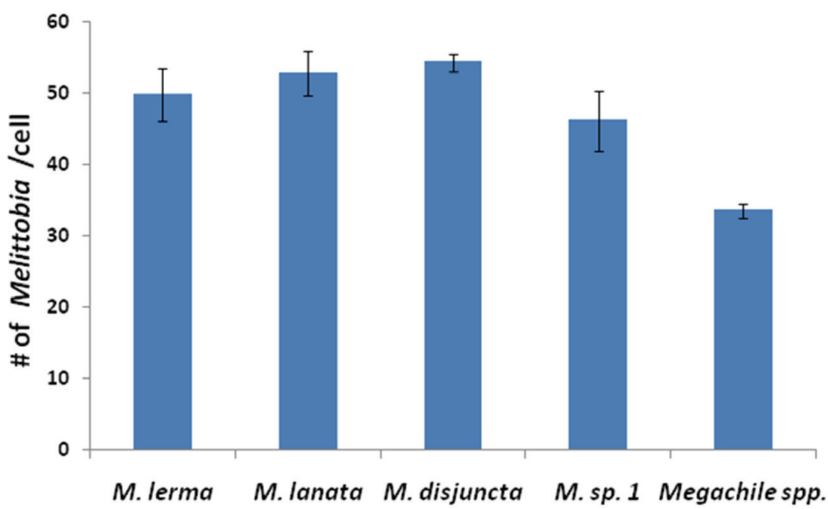

Fig. 5 Number of *Melittobia* adults emerging per cell of *Megachile* spp.

Melittobia spp. have been recorded as important parasitoids of bumble bee colonies and leaf cutting bees in Great Britain, Russia, USA, New Zealand, Japan and Finland (Gonzalez *et al*. 2004; Mathews *et al.,* 2009). *Melittobia hawaiiensis* has been recorded parasitizing *Melitoma segmentaria* (Emphorini: Apidae) in Argentina (Aquino *et al.,* 2015). From India two species of *Melittobia* are recorded- *Melittobia acasta* (Walker) belonging to "*acasta* species group" and *M. assemi* Dahms belonging to "*assemi* species group" (Narendran, 2007). *Melittobia acasta* was found parasitizing *Bombus hortorum* (L.) and *B. ruderatus* (F.) colonies, and *Melittobia* occurred annually in almost all leaf cutting bee nests and killed 64% of 8,370 cells (Macfarlane and Donovan 1989), and also was found parasitic on *Megachile relativa* Cresson in Canada (Dahms, 1984). *Melittobia acasta* parasitized 48.6 per cent of *Megachile rotundata* cells in Hungary (Farkas and Szalay, 1985). *Melittobia digitata* Dahms*, M. australica* Girault, *M. hawaiiensis* Perkins*,* and *M. femorata* Dahms parasitized *Megachile rotundata* in the US (Deyrup, 2005).

The extent of parasitization observed in the present study appears alarming, since 85.55 percent of the bees were killed by *Melittobia* sp. with only 25 leaf cutter bees completing their development out of 173 cells. Though trap nesting has been recommended to increase pollinator nesting sites and for conserving pollinators (Gaston *et al.*, 2005; Tscharntke *et al.,* 1998; Steffan-Dewenter, 2002), Maclvor and Packer (2015) caution us on excessive use of trap nests (which they call 'Bee Hotels'), as the bees and wasps nesting in trap nests may be more prone for parastisation. Our studies on *Melittobia* parasitisation on *Megachile* spp. show exactly this. The very high parasitisation (85.55%) may be because the reeds used for trap nesting were placed in clusters of 15 to 20, and it was easy for the parasites to locate their hosts. Hence, it may be necessary to distribute the trap nests in smaller clusters. Since leaf cutter bees are important pollinators of pigeon pea (Prashanth and Belavadi, 2014) and of several other crops (Abrol, 2012) in India and other parts of the world, it may be important to protect these bees from parasite attacks as well.

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Screening of coleus cultivars for their resistance to root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood and yield under conditions in Kerala

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ABSTRACT: Studies were conducted to find out a resistant variety of *Solenostemon rotundifolius* (Poir) Morton against *Meloidogyne incognita* (Kofoid &White) Chitwood. Two improved varieties (Sree Dhara and Nidhi), five lines from CTCRI (Line-74, 64, 79, 76 and 71) and two accessions (TC-9 and M-131) from Vellanikkara were screened for the relative tolerance to *M. incognita.* The variety Sree Dhara showed significant superiority over the rest of varieties/ lines/accessions in reducing the nematode population (larvae, females, egg masses, eggs per egg mass) in soil and root. This variety had minimum root-knot index of 1.0 and ranked first in yield. The high yielding variety Nidhi closely followed Sree Dhara in yield and resistance to *M.incognita*. Considering the ability to resist nematodes and giving very high yield compared to local variety, Sree Dhara can be the best for cultivation in Kerala followed by Nidhi and CTCRI- 74.

Key words: *Meloidogyne incognita*, *Solenostemon rotundifolius, resistant cultivar*

INTRODUCTION

Roots and tubers are among the world's important food crops, with a great potential to improve food security and alleviate poverty in resource poor countries. Koorka or Coleus, *Solenostemon rotundifolius* (Poir) Morton, a short duration under exploited tuber yielding vegetable best suited for multiple cropping, is extensively cultivated in most of the homestead gardens of Kerala and Tamilnadu. Sathyarajan *et al.* (1966) first reported root knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood infestation in *S.rotundifolius* from Kerala.

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Due to the attack of the nematode, conspicuous gall like swellings are formed in roots and tubers resulting in malformations rendering the tubers unfit for consumption as well as storage. Since nematodes are soil inhabiting pests, application of chemical pesticides adversely affect soil microflora and also cause high level of pesticide residues in harvested produce. The dependence on pesticides can be avoided by identifying a resistant variety against *M. incognita*. In this context, nine varieties/lines/accessions of the crop was screened against *M.incognita*.

MATERIALS AND METHODS

Two improved varieties (Sree Dhara and Nidhi), five lines (Line-74,64,79,76 and 71 of CTCRI), two accessions (TC-9 and M-131 of Vellanikkara) and one local variety (Palappoor) were screened for their relative tolerance to *M.incognita.* The trial was laid out in completely randomized design with three replications. Since the yield potential of the cultivars under Kerala conditions are not known data relevant to that aspect also were collected. The cuttings were planted in pots containing denematized potting mixture. The soil was inoculated with *M.incognita* at an inoculum level of one second stage larva (juvenile) per g of soil 15 days after planting. Denematized soil was applied forty five days after planting also to promote tuberisation. Biometric characters of five observational plants *viz.* height, number of leaves, number of branches were recorded. Population of *M. incognita* was estimated from soil adopting Cobb's sieving and decanting technique (Cobb,1918). Nematode population characteristics (number of larvae in 5g root and 10g tuber, root-knot count, number of females, number of egg masses and average number of eggs per egg mass were recorded at the time of harvest. The root-knot indexing was worked out (Heald *et al*., 1989). Yield in terms of number of tubers per plant (total and marketable), weight of tubers per plant (total and marketable), number of tubers per kg were recorded at the time of harvest.

Quality parameters viz. protein, starch, sugar and crude fiber content of selected varieties (tubers) were assessed at the time of harvest adopting standard methods suggested by A.O.A.C (1975). The data generated were subjected to analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Data on reaction of germplasm of *S. rotundifolius* to *M. incognita* in terms of nematode population characteristics are presented in Table. 1. The performance of variety Sree Dhara was statistically on par with Nidhi giving 222 and 228 lavae per 250g soil respectively at the time of harvest while the nematode population in the root, Sree Dhara differed significantly from other germplasm recording the least number of larvae (40.00 per five g root). Variety Nidhi and CTCRI line-74 supported the larval multiplication in root with mean of 55.33 and 58.33 larvae per five g root respectively. In the case of nematode population in tuber, the Sree Dhara recorded the least number (16.67 per 10 g tuber).The data on root-knot count revealed that all entries showed significant superiority over the susceptible check, Palappoor local except Vellanikkara accession TC-9. The lowest mean gall number of 8.33 per five g root was recorded

Table 1. Population build up of *M. incognita* associated with different cultivars of *S.rotundifolius* and the extend of galling in the varieties

Treatments	Nematode population in			Number of Root-knot in 5 g root	Root-knot index	No. of females (5 g root)	No.of egg masses (5 g root)	Number of eggs per egg mass
	Soil (250 g)	Root (5 g)	Tuber (10 g)					
CTCRI line – 74	276.67 (16.66)	58.33 (7.70)	78.00 (8.86)	23.00 (4.89)	1.67	23.00 (4.89)	12.33 (3.64)	203.33 (14.28)
CTCRI line – 64	282.33 (16.83)	67.67 (8.28)	83.67 (9.20)	31.00 (5.65)	2.00	36.67 (6.13)	20.00 (4.58)	266.67 (16.35)
CTCRI line – 79	295.33 (17.21)	76.67 (8.81)	110.00 (10.53)	44.33 (6.73)	2.00	41.33 (6.49)	27.67 (5.35)	371.67 (19.30)
CTCRI line – 76	313.33 (17.73)	95.33 (9.81)	141.67 (11.94)	49.00 (7.06)	2.33	48.00 (6.99)	31.67 (5.71)	400.00 (20.02)
Sree Dhara	221.67 (14.92)	40.00 (6.40)	16.67 (4.18)	8.33 (3.05)	1.00	7.67 (2.92)	1.67 (1.58)	56.33 (7.56)
CTCRI line – 71	352.00 (18.79)	120.67 (11.02)	162.33 (12.78)	61.00 (7.87)	3.00	62.67 (7.98)	35.00 (6.00)	520.67 (22.84)
Vellanikkara accession – TC 9	384.67 (19.64)	152.67 (12.40)	191.00 (13.86)	70.00 (8.43)	3.00	77.33 (8.85)	44.33 (6.73)	603.33 (24.58)
Vellanikkara accession – M 131	367.67 (19.20)	105.00 (10.29)	177.00 (13.34)	64.00 (8.06)	3.00	65.00 (8.12)	36.67 (6.13)	531.67 (23.08)
Nidhi	228.33 (15.14)	55.33 (7.50)	26.67 (5.25)	14.67 (3.93)	1.00	13.00 (3.71)	5.67 (2.56)	132.33 (11.54)
Palappoor local	391.67 (19.82)	181.67 (13.51)	206.00 (14.38)	77.67 (8.87)	3.67	84.67 (9.25)	49.00 (7.07)	641.67 (25.35)
CD (0.05)	(0.32)	(0.57)	(0.50)	(0.55)	-	(0.62)	(0.52)	(0.78)

Figures in the parantheses are $\sqrt{x+1}$ transformed values

in Sree Dhara with lowest root-knot index of one. Minimum number of females per root was recorded in variety Sree Dhara (7.67 per five g root) and it showed significant superiority over the rest of varieties/lines/accessions. Variety Nidhi and CTCRI line-74 were also statistically independent in reaction with mean number of females of 13.00 and 23.00 per five g root respectively. With regard to the number of egg masses per root, lowest number was recorded by variety Sree Dhara (1.67 per five g root). In the case of average number of eggs per egg mass the lowest was recorded by variety Sree Dhara (56.33). Sree Dhara showed significant superiority over other entries in suppressing the nematode build up as seen in no.of larvae in root and tuber, no. of galls, no. of females, no.of egg masses and no.of eggs per egg mass.

There was statistically significant variation in biometric characters *viz.* plant height, number of leaves, number of branches, plant spread at the time of harvest. Sree Dhara, Nidhi and CTCRI lines (74, 64, 79, 76 and 71) were statistically on par with mean plant height ranging from 55.00 to 63.67 cm. Regarding number of leaves, Sree Dhara, Nidhi, CTCRI-74 and CTCRI-64 were statistically on par with mean leaf number of 650, 646.67, 626.67 and 626.67 respectively. Sree Dhara established its superiority over all other lines / varieties / accessions with mean plant spread of 84.67 cm (Table.2)

The yield of coleus germplasm in terms of total number and weight of tuber per plant are presented in Table 2. In the case of number of tubers, all the varieties/lines/accessions, except Vellanikkara accession M-131 (43.33) and TC-9 (43.00) showed significant superiority over the susceptible check, Palappoor local (42.00). Sree Dhara (81.00) came on par with Nidhi (75.67) and CTCRI line-74 (75). Regarding the marketable tubers Sree Dhara, Nidhi and CTCRI line-74 were on par with mean numbers of 44.00, 41.00 and 38.33 respectively. With regard to the number of tubers per kg weight too the variety Sree Dhara, Nidhi and CTCRI line-74 were on par the number being 85.00, 91.00 and 93.67 respectively. Regarding the total weight of tubers per plant Sree Dhara (550.00 g) was statistically on par with Nidhi (521.67g). The same trend was observed in weight of marketable tubers per plant and edible portion (E.P) of tubers

The changes in protein, starch, sugar and crude fibre content of tubers of selected varieties based on yield attributes are presented in Table 3. In the case of protein content, the performance of Sree Dhara was statistically on par with check, Palappor local giving 8.56 and 8.73 g per 100g dry weight of tubers respectively. Regarding the starch content, the varieties Sree Dhara, Nidhi and CTCRI line 79 came on par showing 18.25, 17.97 and 17.67 g per 100 g dry weight respectively.

Sree Dhara and Nidhi had significantly higher content of sugar than CTCRI lines 79, 74, 64 and Palappoor local, the values being 3.61, 3.46, 3.32, 3.20, 2.95 and 2.54 g per 100 g dry weight of tuber respectively. Regarding the crude fibre content, Sree Dhara, Nidhi, CTCRI lines 74, 64, 79 and Palappoor local came statistically on par the content being 1.05 to 1.40 g per 100 g dry weight of tuber.

Table 2. Growth and yield of different varieties / lines / accessions of *S. rotundifolius* exposed to *M. incognita* infestation

Treatments	Height of plants (cm)	Number of leaves	Number of branches	Plant spread (cm)	Total number of tubers per plant	Total number of marketable tubers per plant	Number of tubers per kg	Weight of total tubers per plant (g)	Weight of total marketable tubers per plant (g)	Weight of edible portion of tubers per plant (g)
CTCRI line – 74	58.00	626.67	42.00	76.67	75.00	38.33	93.67	480.00	390.00	253.33
CTCRI line – 64	57.67	626.67	41.33	75.33	67.33	35.33	94.00	426.67	300.00	230.00
CTCRI line – 79	55.67	580.00	40.67	73.67	57.67	28.33	100.33	411.67	296.67	230.00
CTCRI line – 76	55.00	573.33	40.00	72.33	52.33	27.67	107.00	383.33	280.00	213.33
Sree Dhara	63.67	650.00	45.00	84.67	81.00	44.00	85.00	550.00	446.67	370.00
CTCRI line – 71	55.00	543.33	37.67	72.33	50.67	25.33	109.00	336.67	271.67	213.33
Vellanikkara accession – TC 9	46.67	516.67	35.33	68.33	43.00	25.00	105.67	330.00	236.67	203.33
Vellanikkara accession – M 131	53.00	540.00	36.67	69.33	43.33	23.00	109.00	376.67	270.00	210.00
Nidhi	58.33	646.67	43.33	77.67	75.67	41.00	91.00	521.67	410.00	346.67
Palappoor local	35.00	500.00	35.00	59.00	42.00	22.33	110.00	311.67	223.33	200.00
CD (0.05)	9.79	36.13	4.76	6.62	10.39	5.78	8.93	39.97	37.86	33.92

Table 3. Variation in the chemical constituent of tubers obtained from selected varieties/lines/accessions of *S. rotundifolius* after harvest (mean of three replications)

Treatments	Protein (g / 100 g dry weight of tuber)	Percentage decrease of protein over check	Starch (g / 100 g dry weight of tuber)	Percentage increase of starch over check	Sugar (g / 100 g dry weight of tuber)	Percentage increase of sugar over check	Crude fibre (g /100 g dry weight of tuber)	Percentage change of crude fibre over check
CTCRI line – 74	8.07	7.56	17.35	14.90	3.20	25.98	1.09	-7.63
CTCRI line – 64	8.05	7.79	17.47	15.70	2.95	16.14	1.27	+7.63
CTCRI line – 79	7.88	9.74	17.67	17.02	3.32	30.31	1.18	-
Sree Dhara	8.56	1.95	18.25	20.86	3.61	42.13	1.40	+18.64
Nidhi	8.18	6.30	17.97	19.00	3.46	36.22	1.05	-11.01
Palappoor local (Check)	8.73	-	15.10	-	2.54	-	1.18	-
CD (0.05)	0.21	-	0.58	-	0.16	-	0.38	-

Though all the germplasm exhibited galling, some degree of resistance was expressed by the variety Sree Dhara with 89.00 per cent lesser number of galls when compared to susceptible check, Palappoor local. Based on the nematode population in root, tuber, production of females, number of egg masses per root and number of eggs per egg mass, the reaction of the variety Sree Dhara was significantly better than other germplasm. Similar resistance reactions in carrot, brinjal, ginger and african yam cultivars against *M. incognita* were reported earlier by Arya and Tiagi (1982), Ravichandra *et al*. (1988), Eapen *et al*. (1998) and Mohandas *et al*. (1998). They reported moderately resistant varieties / cultivars with a root-knot index ranging from 1 to 1.5. In this study Sree Dhara and Nidhi recorded a root-knot index of one and hence can be categorized as moderately resistant.

Regarding the biometric characters and yield, the variety Sree Dhara performed better than the other entries and it was statistically on par with variety Nidhi and CTCRI-74 in most of the characters. The susceptible check, Palappoor local recorded lowest content of total sugar and starch, while least reduction of the above was observed in moderately resistant variety Sree Dhara. Along with varietal influence the differences in nematode damage also might contribute to the difference in starch and sugar content. Tayal and Agarwal (1982) reported 23.00 and 59.34 per cent reduction in total sugar and starch content of brinjal seedlings (variety Pusa Purple Long) by *M. incognita* infestation.

As shown by the results considering the ability to resist nematodes and giving very high yield compared to local variety/cultivar Sree Dhara can be the best for cultivation in Kerala closely followed by Nidhi and CTCRI- 74.

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Effect of alternate food sources on biological parameters of *Stethorus pauperculus* Weise (Coleoptera: Coccinellidae)

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ABSTRACT: The effect of different alternate food sources on survival, mating frequency, fecundity and egg hatchability of *Stethorus pauperculus* was tested under laboratory conditions. None of the alternative hosts was able to maintain fertility of the female *S. pauperculus*, except the primary hosts which included two spotted red spider mite (*Tetranychus urticae* Koch), sorghum mite (*Oligonychus indicus* (Hirst)) and yellow mite (*Polyphagotarsonemus latus* (Banks)). Although some eggs were laid when *S. pauperculus* was supplied with pollen and honey mixture, they did not hatch. The most effective food source for maintaining adult longevity was *T. urticae* (39.30±1.08 days), followed by sorghum mite, *O. indicus* (29.75±0.67 days) and yellow mite (25.25±0.78 days).

Key words: *Stethorus pauperculus,* alternate food sources, biological parameters

Several natural enemies of spider mites have been recorded all over the world (Granham, 1985). Among them the beetles belonging to family Coccinellidae are predators of spider mites specially *Stethorus* spp. are specialized mite predators in Coccinellidae (Felland and Hull, 1996; Hoy and Smith, 1982 and McMurty *et al.,* 1970). The ladybird beetles of the genus *Stethorus* (*Stethorus punctillum, S. gilvifrons*, *S. punctum picipes*) are the most effective natural enemies of the phytophagous mite species *Tetranychus piercei* McGregor, *Panonychus citri* McGregor, *Panonychus ulmi* (Koch) and *Tetranychus urticae* Koch (Lui and Lui, 1986; Lorenzato, 1987; Wen, 1988; Pasualini and Antropoli, 1994; Cakmak and Aksit, 2003; Gencer *et al.,* 2005; James *et al.,* 2001 and Perez *et al.,* 2004). *Stethorus pauperculus* Weise is one of the most effective-coccinellid predators of the two-spotted spider mite. Their larval and adult stages feed on different stages of the two-spotted spider mites.

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Puttaswamy and ChannaBasavanna (1977) reported *S. pauperculus* as feeding on spider mites infesting papaya, castor, citrus, jasmine and various crops in Bangalore, India. The aim of the present work was to study the effects of different alternative food sources on some biological parameters of *S. pauperculus* in order to mass rear in case of the lack of natural food supply *viz.,* spider mite.

The experiments on rearing of *S. pauperculus* on alternative food sources were carried out at Acarology laboratory, Department of Entomology, N. M. College of Agriculture, Navsari Agricultural University, Navsari during March 2013 to May 2013 at room temperature. Twenty pairs of newly emerged beetles were randomly selected from the stock culture and paired in 20 replicates in each of the potential food source in modified Petri dishes. Parameters such as rate of predation, mating, fecundity, egg hatchability and adult longevity of paired adult *S. pauperculus* were measured in the laboratory on different hosts. The treatments details are as follows:

T_1- Starved (No food)

T_2- Water only

T_3- Honey and water

T_4- Pollen and honey

T_5- Groundnut aphid, *Aphis craccivora* Glover (mixed stages *i.e.* nymphs and adults)

T_6- Whitefly, *Bemisia tabaci* (Gennadius) (Eggs only)

T_7- Sorghum mite, *Oligonychus indicus* (Hirst) (All stages)

T_8-Two-spotted red spider mite, *Tetranychus urticae* (Koch) (All stages)

T_9-Yellow mite, *Polyphagotarsonemus latus* (Banks) (All stages)

The above diets were exposed to adult *S. pauperculus* inside modified Petri dishes. The base was covered with dry filter paper to absorb any excrement of host or predators, thereby preventing contamination. The number and quantity of each food type was consistent in each treatment except for Treatment-1 (Starved). In each dish an uninfested french bean leaf disc was supplied daily to the pair for oviposition. In Treatment-2, water was supplied constantly through a cotton roll placed on the mesh screen, and was renewed daily. In Treatment-3, honey diluted with water in a ratio of 3:1(v/v) was provided in the same manner as in Treatment-2. These cotton rolls were renewed every second day, to prevent the rolls from becoming dry and also to avoid any risk of contamination. In Treatment-4, castor pollen obtained by shaking the inflorescences on white papers was mixed thoroughly with honey and supplied in a small plastic lid (3 mm diameter)placed on the dry filter paper. The mixture of pollen and honey was replaced every two days, because it developed fungal growth if kept longer. The numbers of aphid, whitefly eggs, and sorghum mites were counted carefully under a stereo zoom binocular microscope on the host leaves before the predators were confined. After 24 hours feeding period the pairs of *S. pauperculus* were transferred to new containers and the remaining numbers of each host were counted and recorded. Mating, fecundity and longevity of *S.*

pauperculus were determined by observing all dishes at 12 hour interval. The number of eggs laid was counted and the period between adult emergence and death was calculated as longevity. Each treatment was repeated five times and in each repetition 15 pairs were placed. Thus, the data so obtained were calculated by using mean and SD.

The effect of alternate hosts on survival, mating, frequency, fecundity and egg hatchability of *S. pauperculus* is summarized in Table 1. Mating was not recorded on any host treatment except for sorghum mite, two-spotted red spider mite and yellow mite and hence no oviposition was recorded on these hosts. The mean mating frequency recorded was 12.40 times on two-spotted red spider mite was 6.85 times on yellow mite and 6.45 times on sorghum mite as compared to other alternative hosts. The fecundity was highest on two-spotted spider mite with 91.65 eggs per female followed by those on sorghum mite (71.60 eggs per female) and yellow mite (56.85 eggs per female). A few eggs were laid in pollen and honey mixture (5.0 eggs per female) while on other alternate hosts not a single egg was laid by the female beetles. The same pattern was also recorded in case of number of eggs laid per day where the beetles that fed upon the two-spotted red spider mite laid the maximum eggs per day, followed by those females feeding upon sorghum mite and yellow mite. The minimum eggs per day were laid by those females which fed on pollen and honey mixture as alternate food. The egg hatchability was also greater on primary hosts, *i.e.* two spotted red spider mite, sorghum mite and yellow mite (92.38±4.146, 86.19±3.360 and 74.59±7.651 per cent, respectively). A few eggs were laid in the pollen and honey mixture treatment, but they did not hatch and were considered to be non-viable. The adult longevity varied in all the treatments. In case of female it was highest in the two spotted red spider mite treatment (39.30±1.089 days) followed by the treatments on sorghum mite (29.75±1.069 days) and yellow mite (25.25±0.783 days). It was lowest in case of the treatment with starved beetles (3.94±0.841 days) and followed by the treatment with *A. craccivora* as food (4.45±0.514 days). In case of males, the same trends were observed. The longevity of male beetles was maximum when provided with the primary host, two spotted red spider mite (35.25±0.442 days), followed by sorghum mite (25.40±0.827 days) and yellow mite (23.45±0.514 days). The minimum male longevity was recorded in case of the treatment consisting of groundnut aphid, *A. craccivora* (3.25±0.442 days) and in the treatment with starved beetles (3.60±0.506 days).

In the present study no mating or oviposition was recorded for *S. pauperculus* on any hosts, except on its primary hosts like two spotted spider mite, sorghum mite and yellow mite and castor pollen and honey. The mean number of eggs laid by females fed on castor pollen and honey mixture was 5.0±1.129 per female which was very low as compared to its primary hosts, *viz.,* two-spotted spider mite (92.38±4.146), sorghum mite (86.19±3.360) and yellow mite (74.59±7.651). Further, eggs laid in pollen and honey mixture treatment did not hatch, whereas egg hatchability in case of treatments with primary host were very high. Adult longevity increased with the provision of alternative hosts such as water only, honey and water, castor pollen and honey, aphid and white fly eggs but no reproduction occurred on these hosts. The descending order of adult longevity in relation to hosts was two spotted spider mite > sorghum mite > yellow mite > castor pollen and honey > honey and water > water only > white fly

Table 1: Effect of alternative food hosts on biological parameters of *S. pauperculus*

Treatments	Mating	Total fecundity	Daily fecundity	% hatching	Adult longevity (Days)	
					Female	Male
T_1:No food (Starvation)	0.00	0.00	0.00	0.00	3.94±0.84	3.60±0.51
T_2:Water only	0.00	0.00	0.00	0.00	8.55±1.05	6.55±0.68
T_3:Honey and Water	0.00	0.00	0.00	0.00	17.95±0.83	16.35±0.58
T_4: Castor pollen and honey	0.00	5.00±1.13	0.50±0.11	0.00	21.45±1.35	19.30±0.47
T_5:Groundnut aphid (*A. craccivora*)	0.00	0.00	0.00	0.00	4.45±0.51	3.25±0.44
T_6: Whitefly (*B. tabaci*)	0.00	0.00	0.00	0.00	6.30±0.74	4.35±0.48
T_7:Sorghum mite (*O. indicus*)	6.45±1.44	71.60±6.46	7.16±0.65	86.19±3.36	29.75±1.07	25.40±0.83
T_8:Two spotted spider mite (*T. urticae*)	12.40±2.47	91.65±7.35	9.12±0.77	92.38±4.15	39.30±1.09	35.25±0.44
T_9: Yellow mite (*P. latus*)	6.85±1.65	56.85±6.56	5.68±0.66	74.59±7.65	25.25±0.78	23.45±0.51

Mean ±SD of 5 repetitions

(Eggs) > groundnut aphid (all stages) > starved (no food). The present results with *S. pauperculus* are similar to the reports of Putman (1955) and Kehat (1967) who also concluded that *S. punctillum* fed on aphid, phytoseiid mites and scale insects but these hosts were not sufficient for development or oviposition. Kamiya (1966) and Hoy *et al.* (1979) reported that *S. japonicas* fed on plant resins, sweet foliar secretions and honey and water, which increased the longevity but did not result in copulation or reproduction. Bakr and Genidy (2009) also found similar results in case of *S. punctillum* at Cairo, Egypt. Oviposition was not recorded when *S. punctillum* was reared on any alternate food but the adult longevity was highest when fed on a mixture of honey droplets, pollen grains and royal jelly, while the shortest period was recorded when the predator was starved or fed on aphid. Most of the coccinellids are predaceous on insects in the order Hemiptera, but species of *Stethorus* feed almost exclusively on spider mites. When primary prey is scarce, *Stethorus* are reported to eat other foods such as aphid, whiteflies, honeydew, pollen gains, nectar and sweet sap or may even elicit cannibalistic behaviour. While some species of *Stethorus* feed on a range of tetranychid species, others are more specific such as *S. pauperculus* as in the present case which do not readily feed or oviposit on other mite species. The present results will be useful for mass rearing and release of the predator under green house and open field conditions against spider mite pests in various high value crops.

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